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WHAT YOUR BRAIN DOES TO CREATE REALITY

Science Focus

Why people think
THEY CAN HEAR THE DEAD

How to beat
COVID-19 BY 2022

How to teach
A MACHINE TO TELL A STORY

DARK STARS

How a string of strange discoveries could reveal a cosmos hidden just out of view

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FROM THE EDITOR

Forgive us if we indulge in a little escapism this month. After a soggy, concrete-grey January cooped up inside, we decided to go with something otherworldly for this issue: ghost stars. If you've subscribed to us for a while, you'll know that scientists are on the hunt for dark matter, an elusive but all-pervasive material that seems to hold our Universe together. Though we can't see it, interact with it, or – most crucially – detect it with our most sensitive instruments, we can see that something is holding galaxies together, keeping the stars inside from spinning further out into space. This might seem inconsequential, but our best calculations estimate that this dark material seems to outweigh normal matter by a factor of six to one.

It's clear to see why scientists have become increasingly desperate to find a way to detect and measure dark matter, and why a series of strange new signals in a handful of experiments dotted around the globe has got researchers excited. To get to the bottom of this mystery and the incredible ideas underlying it, head to p70 where astronomy writer Colin Stuart reveals all. In the meantime, if you want to listen to interviews that explore the ideas covered in the magazine in greater depth, please do check out our podcast, which you can find at **sciencefocus.com/podcast**.

Enjoy the issue!

Daniel Bennett, Editor

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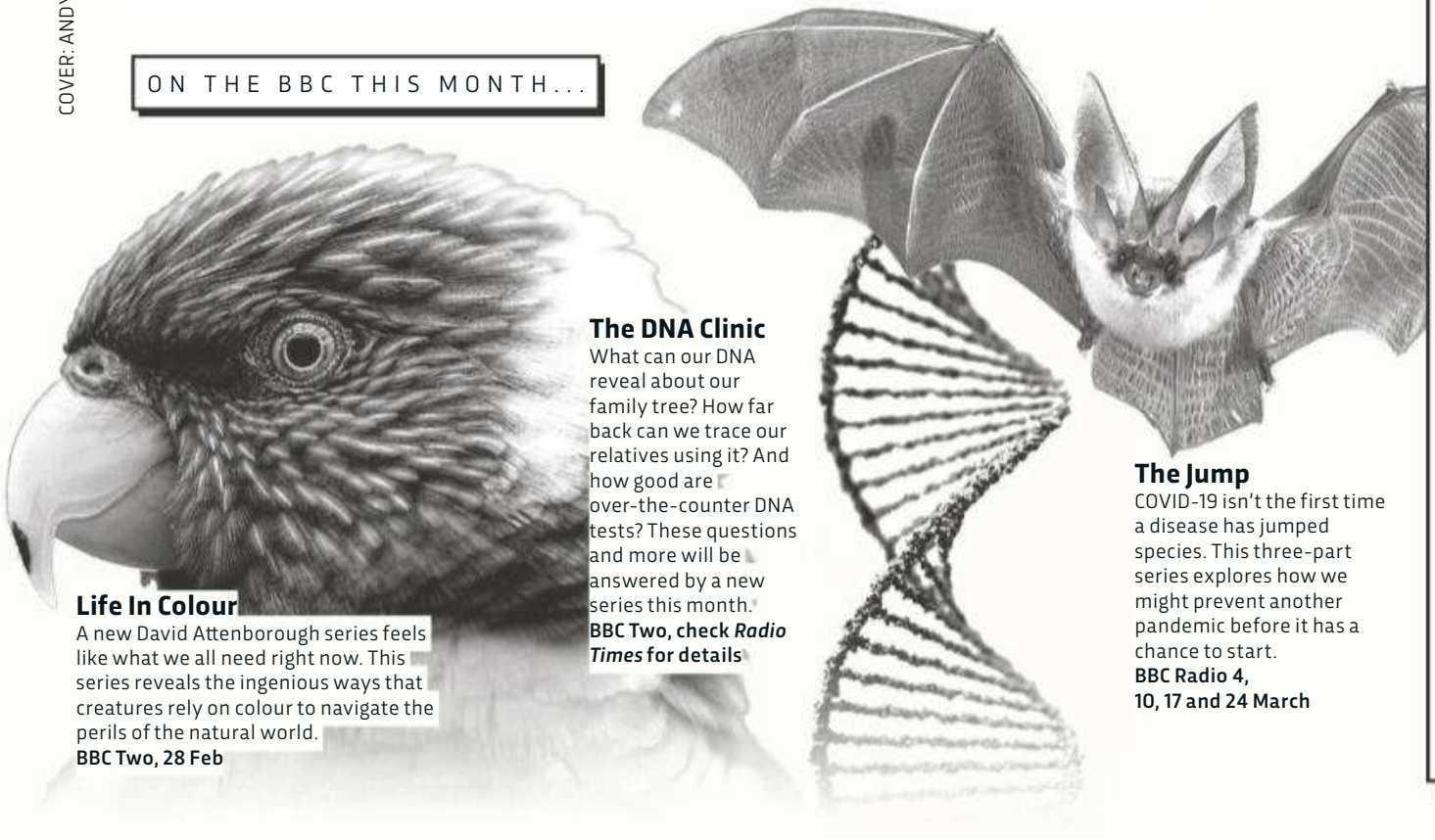
ON THE BBC THIS MONTH...



Life In Colour
A new David Attenborough series feels like what we all need right now. This series reveals the ingenious ways that creatures rely on colour to navigate the perils of the natural world.
BBC Two, 28 Feb

The DNA Clinic
What can our DNA reveal about our family tree? How far back can we trace our relatives using it? And how good are over-the-counter DNA tests? These questions and more will be answered by a new series this month.
BBC Two, check *Radio Times* for details

The Jump
COVID-19 isn't the first time a disease has jumped species. This three-part series explores how we might prevent another pandemic before it has a chance to start.
BBC Radio 4, 10, 17 and 24 March

Could we farm thunderstorms for power? →p79

CONTRIBUTORS

LOIS KING
Lois is a researcher at the Global Health Unit on Respiratory Health in Asia at the University of Edinburgh. She looks at how we could beat COVID in 2022. →p36

DR LISA FELDMAN BARRETT
Lisa is one of the most cited neuroscientists on the planet. She explores how brains create reality, and what happens when things go wrong. →p54

DR LARA MARTIN
Wouldn't it be nice if you could just speak naturally to your smart speaker to get it do what you want? That's exactly the problem Lara is attempting to solve. →p66

COLIN STUART
Colin has an asteroid named after him in recognition of his popularisation of astronomy. Who better to help us understand the mysterious world of dark bosons? →p70

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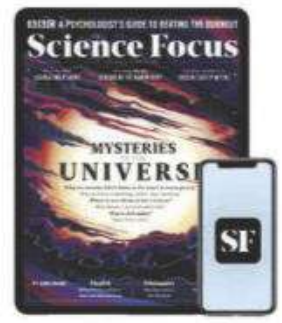

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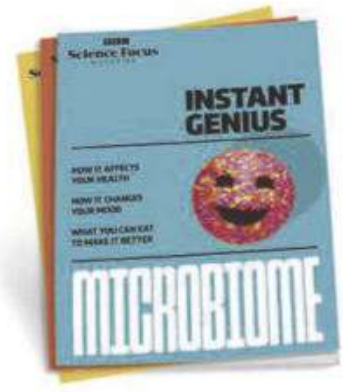

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A collection of the most important ideas in science and technology today. Discover the fundamentals of science, alongside some of the most exciting research in the world.

EYE OPENER

Future farm

SAN FRANCISCO, US

San Francisco agricultural start-up, Plenty, hopes to tackle rising food demands at its innovative vertical farm. As it is indoors, pesticides can be limited and the crops are not damaged by weather extremes. Artificial intelligence controls planting, temperature, moisture and light, and learns how to improve crop production. Plenty claims it uses 99 per cent less land than typical farms.

LettUs Grow in Bristol, UK, also uses software in its indoor vertical farms. "Looking ahead, vertical farming will enable us to control the shape and fragrance of crops, creating opportunities to engineer and cultivate biopharmaceuticals like vaccines in plants," says Dr Antony Dodd, a scientist at LettUs Grow.

Currently, temperature and lighting systems limit the environmental credentials of vertical farms. However, both Plenty and LettUs Grow aim to integrate renewable energy to 'close the loop' in their vertical farms.

COVER IMAGES

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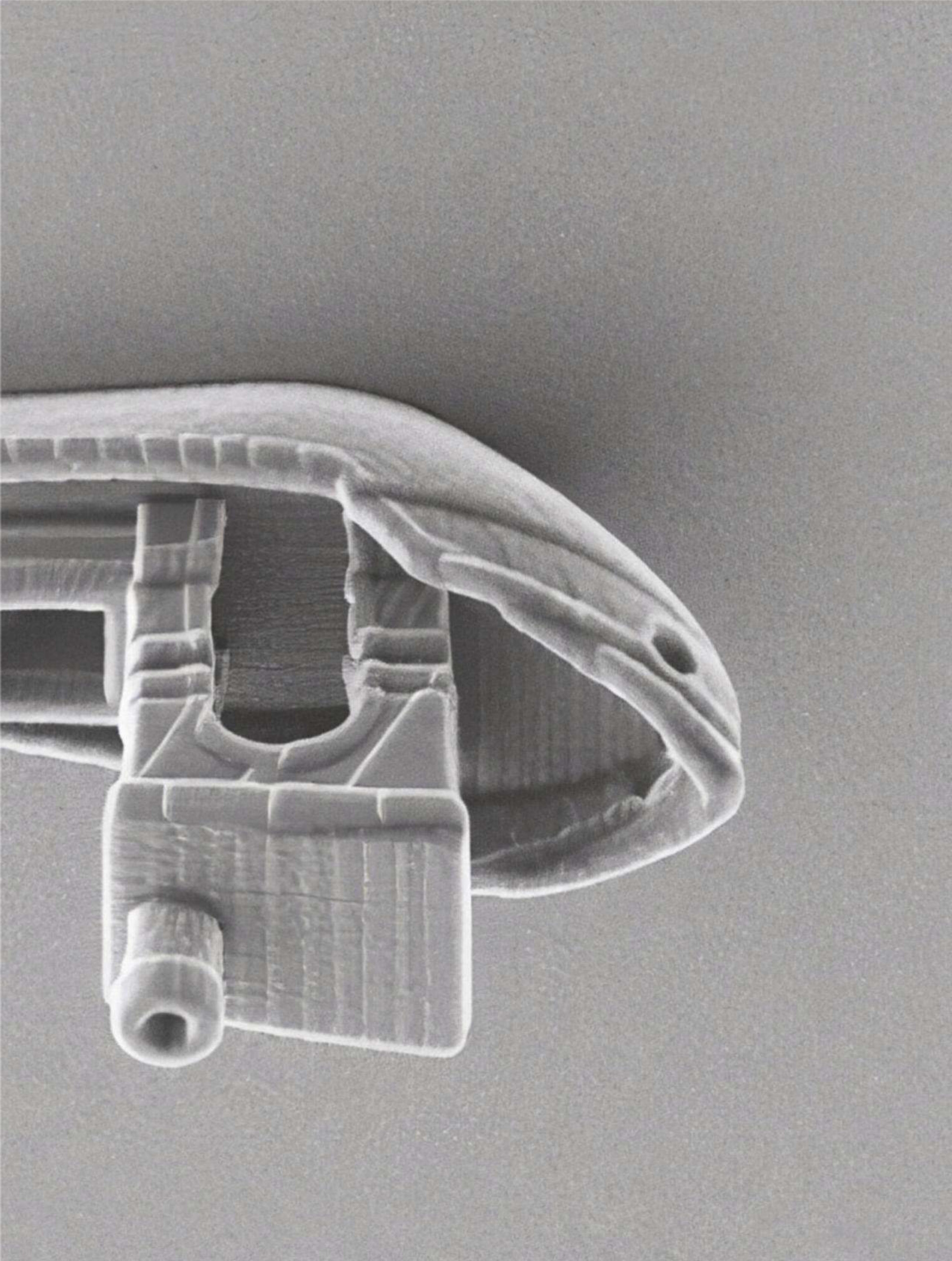

EYE OPENER

All aboard!

LEIDEN,
THE NETHERLANDS

Researchers at Leiden University 3D-printed this boat that's invisible to the naked eye. At 30 microns, the tiny vessel is close in size to a human skin cell.

The team studies 'microswimmers', which are biological or synthetic particles that move through fluids. They built microswimmers of various designs and observed their movements using an electron microscope, noting that spiral shapes made faster swimmers.

After 3D-printing the boat, a layer of platinum was applied. "It works as a catalyst and breaks down hydrogen peroxide or water [in the fluid it travels through] as a fuel to propel itself," says researcher Dr Rachel Doherty.

Microswimmers could one day be used in diagnostics or drug delivery. "Understanding the influence of shape on motion will help in future applications," says Doherty. "The idea is to create a vehicle to transport a drug to a targeted location in the body."

LEIDEN UNIVERSITY

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EYE OPENER

Put your face on

TOKYO, JAPAN

Shuhei Okawara has taken face masks to the next level by creating these hyper-realistic, 3D-printed designs. While they're not medically approved, these masks will reach a niche market when they go on sale this year. They are set to sell for 98,000 yen (almost £700) each in Okawara's Tokyo store Kamenya Omote.

Inspired by fantasy stories, Okawara used advanced 3D-printing technology to create the masks from models' photos. When he launched the project last year, more than 100 applicants sent him headshots, expressing their interest in modelling for the masks. He plans to expand the range of faces after the initial launch, so there will be a choice of which mask to wear.

We are yet to learn more about the engineering behind this specific project, but Okawara is working closely with an unnamed printing engineer and claims that they'll be able to create up to 100 identical masks a month.

REUTERS

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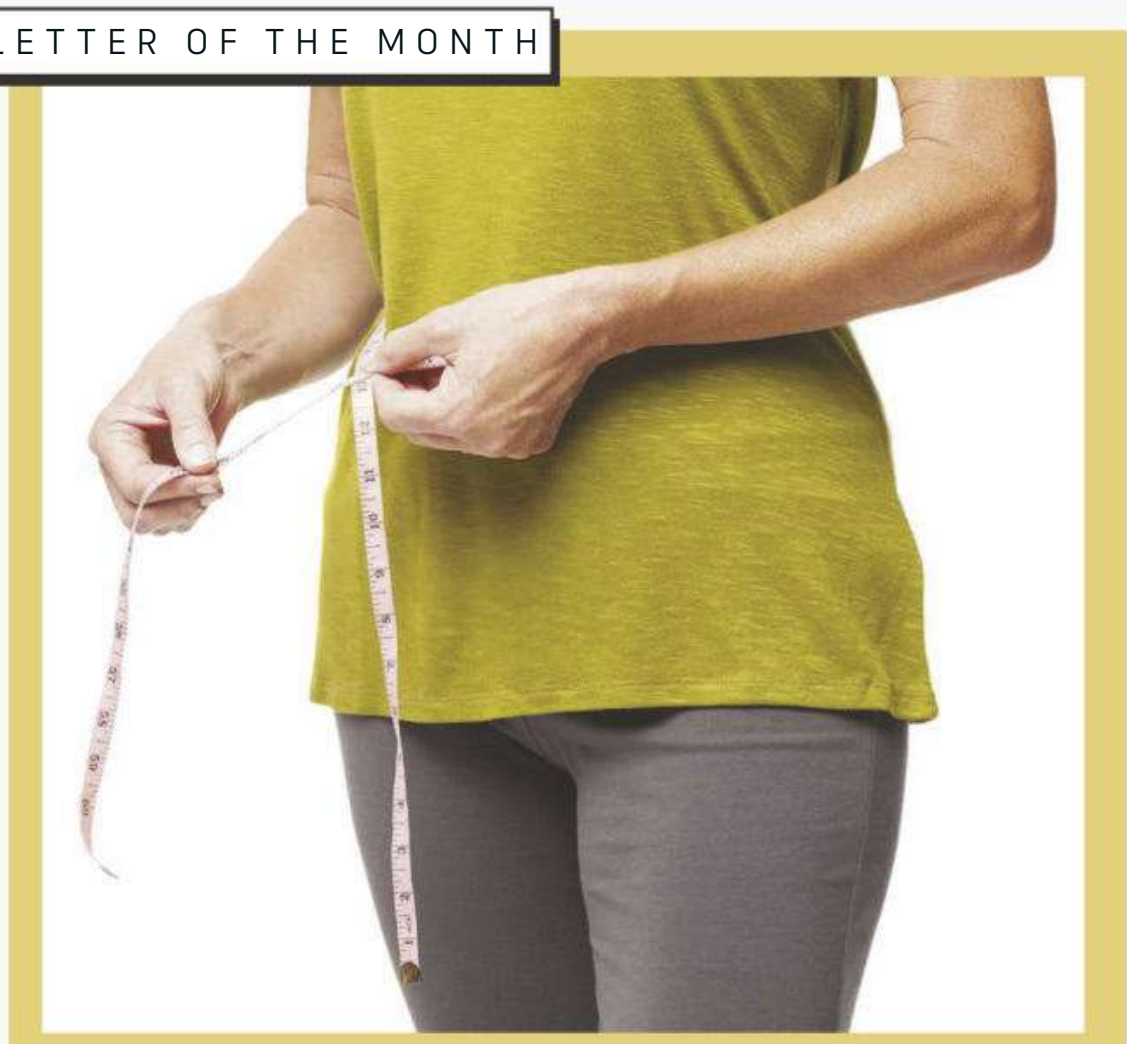
LETTER OF THE MONTH



Tim Saviour

I KNEW IT! I used to be able to eat and drink anything, but since becoming menopausal I have struggled with my weight.

So, I exercised like a maniac for four years (all differing types) and I watched what I ate. I would lose weight at first but then it would creep back up. Reading Prof Tim Spector's article about diet myths (November, p56) gave me a sign of relief... I am not going mad, I am just getting older and my body doesn't process food the way it used to! Thank you, Tim, for giving me my sanity back!

Shamsi Pearson

WRITE IN AND WIN!

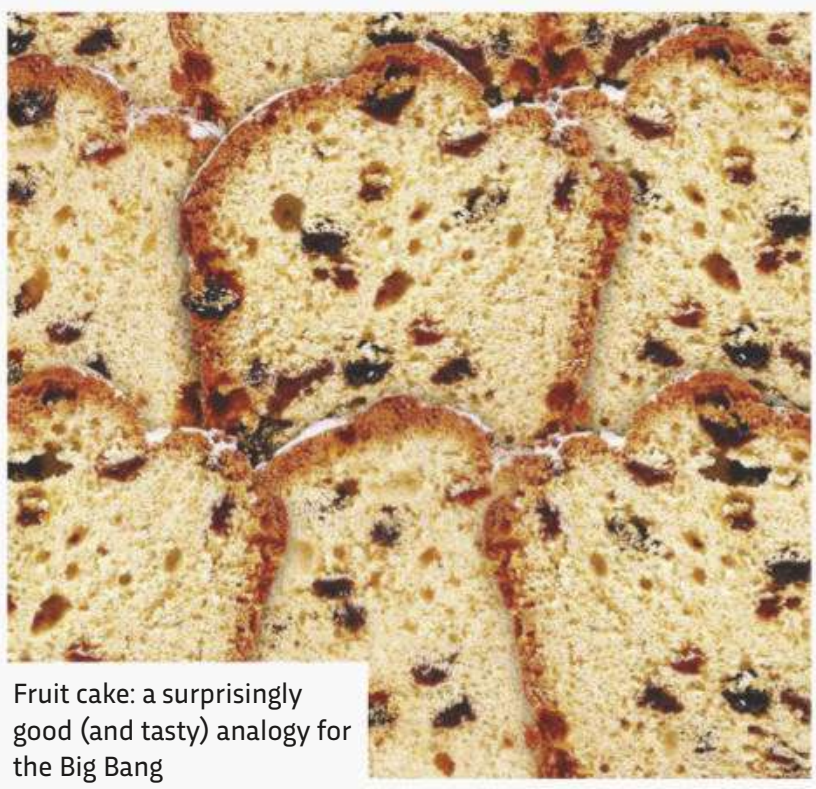
The writer of next issue's *Letter Of The Month* wins a **Let's Explore Oceans mega pack**. It comes with a set of VR/AR goggles, powered by your smartphone, to take you on an immersive journey through the sea. Learn about the anatomy of great whites and humpback whales, before practising your underwater photography skills. **letsexplore.com**

Out with a bang

The December issue was my favourite for some months, because it contained more physics than usual. However, I had a question regarding the Big Bang. In any explosion, all the exploding material, mass and energy, travels outwards from the origin, leaving a continuously expanding vacuum at the centre, which by now would add up to a mind-bogglingly enormous empty volume in interstellar space. So where is it? Unlike the Higgs boson, it shouldn't be hard to spot, surely?

Mark Farren

The Big Bang is often likened to an explosion, in the sense that a lot of stuff moved apart quickly. But it wasn't literally an explosion, and the metaphor rapidly falls apart. In an explosion, you have a centre where the combustion happens, and things move away from that centre at high speeds. But with the Big Bang, there is no literal 'bang', and there's also no centre: the Big Bang happened everywhere at once. It's hard for us to picture, but a metaphor that cosmologist



Fruit cake: a surprisingly good (and tasty) analogy for the Big Bang

"HAVING AN AI ACTUALLY PLAY DUNGEONS & DRAGONS IS AN ASPIRATIONAL GOAL, SOMETHING I'D LIKE TO SEE THE COMMUNITY COME TOGETHER TO TACKLE"

DR LARA MARTIN, P66

Cats are more discerning than *Science Focus* experts, says Emily Johnston

ALAMY, GETTY IMAGES X2

Marcus Chown uses is raisins in a fruit cake. As the cake rises in the oven, all the raisins move away from all the other raisins – they don't radiate out from the centre of the cake.
Sara Rigby, online assistant

The cat's wet whiskers

Maybe Tim Spector can't tell the difference between tap water and bottled water (November, p61) but my cat can, and he will absolutely not touch the tap water. I buy gallon jugs of spring water to put in his water dish. I have a good nose and I can pick up the smell of chlorine in the water, which is why I assume he won't drink it. He was raised on well water – no chlorine.
Emily Johnston, Sykesville, US

Life on Europa

Reading about the possibility of extraterrestrial life existing purely underwater (December, p58) got me thinking about what kind of intelligent life could evolve in a world that was fully submerged. Sure, there could be fish-like and crab-like creatures, but could intelligence ever go much further than that? Would an underwater world ever warrant the use of tools? Fire seemed necessary for many of our accomplishments, and this would be out of the question. Even simple things, like a wheel, led to the invention of complex mechanical systems. However, there would be little use for a wheel in the ocean, so that entire line of innovation would be obsolete. The shark has changed very little in hundreds of millions of years, so it's possible that this is the best we could ever expect.

I'm sure if we do find life on Europa it would be microbial at best, but it's fun to imagine what beasts could be lurking there.
Pad Scanlon, London

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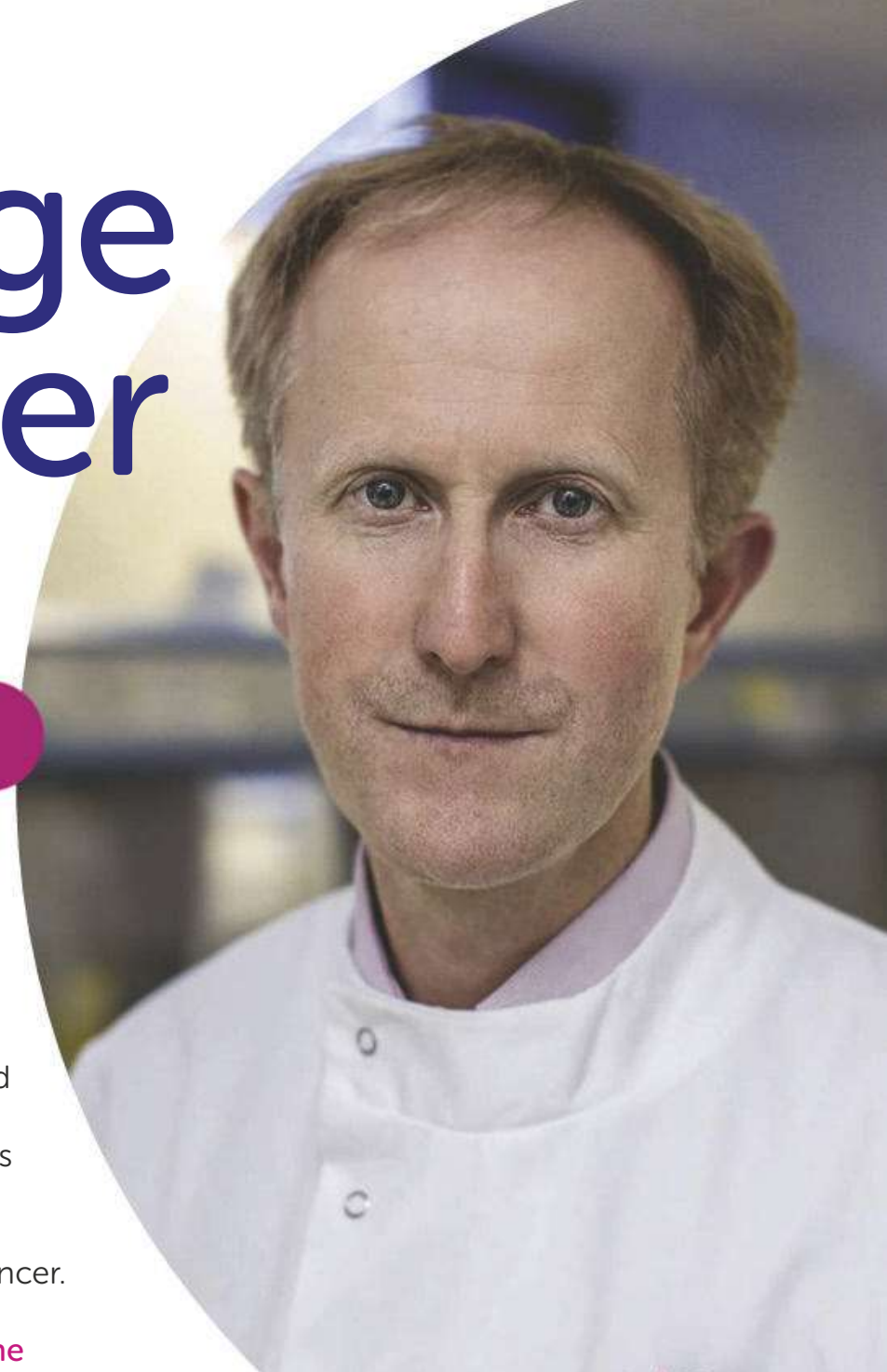
Make a pledge to beat cancer



This is Professor Duncan Baird. He's made a pledge to help beat cancer and Cancer Research is commited to helping him. Help them both by making a pledge to leave a gift in your Will

How important is Cancer Research UK's funding to your work?

It's absolutely fundamental. Without it I couldn't have continued as a research scientist and would have ended up changing career. My lab is supported by Cancer Research UK via a five-year programme grant. This funding provides stability and allows us to develop more ambitious programmes than we could on a standard three-year research contract.

Why did you get into researching cancer?

Initially it was intellectual curiosity and the hope that my work might help patients. On a more personal level, both of my parents died of cancer. For both, it was very sudden and brutal. My mother went from diagnosis to death in a matter of months and didn't get to say goodbye to her family. It's for people like my parents that I want to keep working to understand cancer and develop more effective therapies.

What are you researching at the moment?

Telomeres – the structures that cap the ends of chromosomes, protecting them from damage. Telomeres also play a role in cancer development and ageing.

Our lab has developed the highest resolution approach for measuring the length of telomeres. We've also defined the length at which telomeres become dysfunctional and chromosomes start to get damaged. In collaboration with Professors Fegan and Pepper of Cardiff University, we've shown that telomere length can be used to predict survival and the response to treatment of patients with blood cancers, including chronic lymphocytic leukaemia, multiple myeloma and breast cancer.

How optimistic are you about the future of cancer treatment?

I'm very optimistic. While the mainstay of cancer treatment remains toxic chemotherapies, the efforts of research in the last 30 years to gain a deeper understanding of cancer are now bearing fruit. New targeted agents are becoming available, some of which have transformed the outcomes of cancer patients.

Did you know that one third of all Cancer Research UK funding comes from Gifts in Wills?

I knew that a significant amount of Cancer Research UK funding came from Wills. It's inspiring to think that so much of the funding that keeps our lab going has come from people who have sadly passed away, but have pledged to give money that can be put towards finding more effective therapies for cancer patients.

Pledge to leave a gift in your Will

Cancer Research UK funds nearly 50% of all cancer research in the UK and the best way you can contribute to that funding is through a gift in your Will. A pledge to leave Cancer Research UK a gift in your Will is a great way to help beat cancer. Gifts help to continue the search for new ways to diagnose the disease early and better ways to treat it. There are many types of gifts you can leave in your Will, such as a specific amount or item, but a 'residuary' gift is likely to be the most valuable way to give to charity. A residuary gift is a share or percentage of your estate that's inflation-proof, so it will never lose value.

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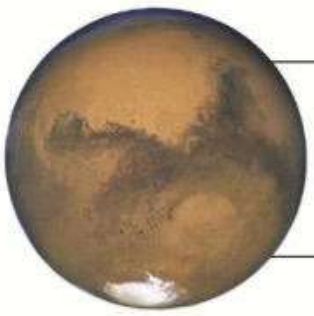
Together we will beat cancer

Cancer Research UK is a registered charity in England and Wales (1089464), Scotland (SC041666), and the Isle of Man (1103) and Jersey (247).



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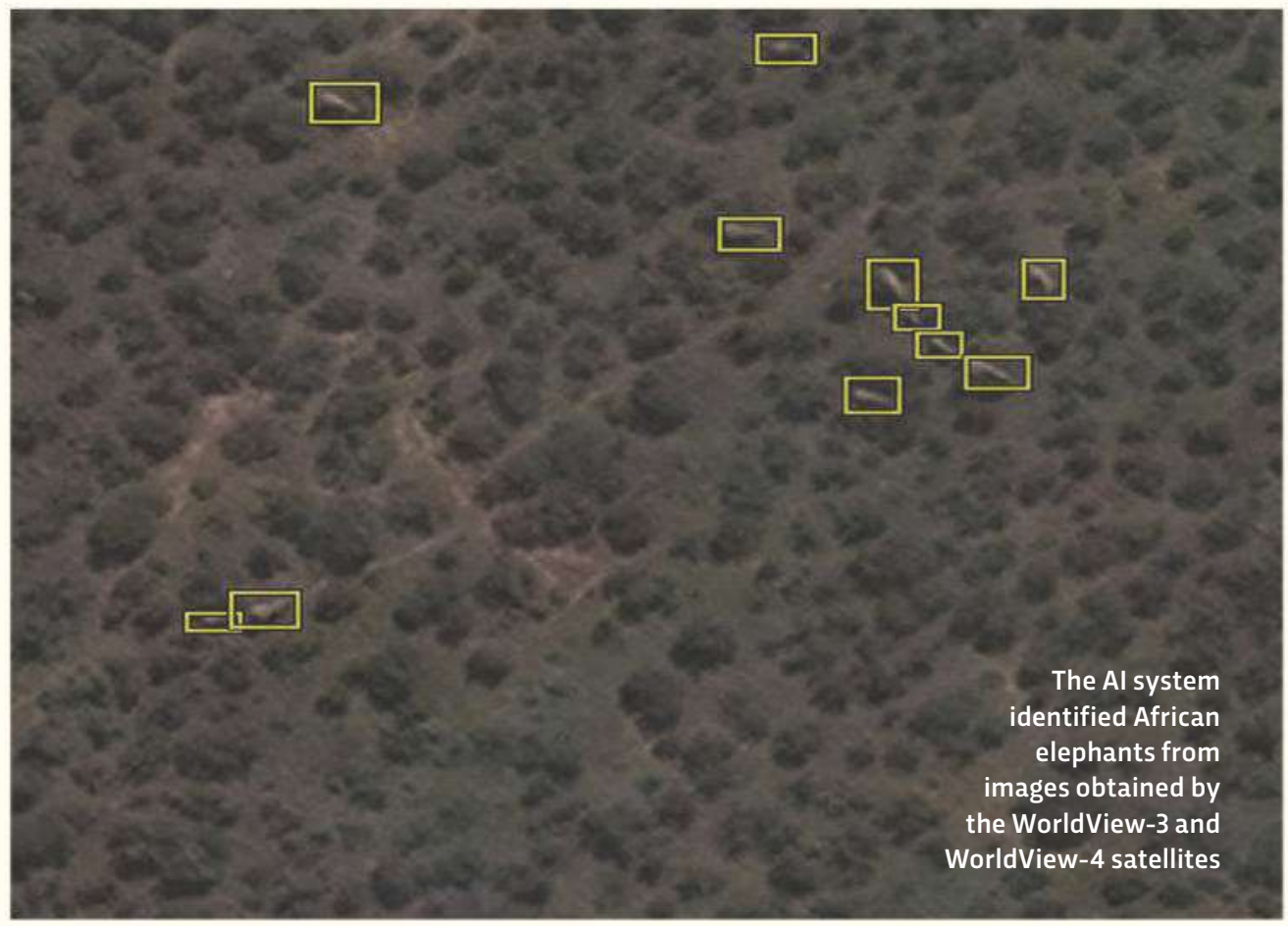
ENDANGERED ELEPHANTS TRACKED FROM SPACE BY ARTIFICIAL INTELLIGENCE

The world-first study opens the door to more effective methods of monitoring the movements of endangered species

GETTY IMAGES

Powerful friends Electric eels will join forces to zap their prey p23 **Virgin flight** On its first successful flight, Virgin's LauncherOne craft takes 10 tiny CubeSats into orbit p26 **Down the rabbit hole** Primordial black holes could contain baby universes p28

Satellites are able to cover large areas, and can monitor regions that are inaccessible from the ground



The AI system identified African elephants from images obtained by the WorldView-3 and WorldView-4 satellites

An international team of scientists from the University of Bath, the University of Oxford and the University of Twente in the Netherlands have successfully used satellite-based cameras coupled with deep-learning algorithms to track the movements of African elephants.

The population of African elephants has plummeted over the last few decades, thanks to poaching and loss of habitat. The species is now classified as endangered, with just 50,000 individuals left in the wild.

Currently, conservationists monitor the populations of endangered and under-threat animals such as elephants by counting them one-by-one from low-flying aeroplanes. But in this study, the team used an automated artificial intelligence system created by Dr Olga Isupova, a computer scientist at the University of Bath, to analyse high-resolution images of the elephants as they moved through forests and grasslands. The images had been captured by the commercially run WorldView-3 and WorldView-4 observation satellites. They found that their system was able to examine the images and identify the animals with the same accuracy as humans analysts.

Although the combination of satellite imagery and deep-learning has previously been used to identify marine animals, this study marks the first time the technique has been used to monitor animals moving through a mixed landscape that includes areas of open grassland, woodland and scrub.

“Accurate monitoring is essential if we’re to save the species. We need to know where the animals are”

“This type of work has been done before with whales, but of course the ocean is all blue, so counting is a lot less challenging. As you can imagine, a heterogeneous [diverse] landscape makes it much harder to identify animals,” said Isupova. “Accurate monitoring is essential if we’re to save the species. We need to know where the animals are and how many there are,” she added.

The team chose to run their pilot study using African elephants, as they are the largest land animals and therefore the easiest to spot. However, the researchers are hopeful that the technology will be successful in observing other species in the future.

“Satellite imagery resolution increases every couple of years, and with every increase we will be able to see smaller things in greater detail. Other researchers have managed to detect black albatross nests against snow. No doubt the contrast of black and white made it easier, but that doesn’t change the fact that an albatross nest is one-eleventh the size of an elephant,” said Isupova. “We need to find new state-of-the-art systems to help researchers gather the data they need to save species under threat.”

MARS

Glaciers on Mars reveal the planet went through multiple ice ages

The discovery could help establish how the Martian climate has changed over time

Glaciers that have remained on the surface of Mars for hundreds of millions of years are revealing secrets of the planet's unique geological past.

By analysing the patterns and structures of rocks in 45 of the Red Planet's glaciers, researchers at Colgate University, New York, have found that Mars underwent between 6 and 20 separate ice ages over the last 300 to 800 million years.

The team made the discovery after painstakingly poring over a series of high-resolution images collected by the Mars Reconnaissance Orbiter satellite, and measuring the size of around 60,000 rocks in the photos.

If there was a single, long ice age event, they would've expected to find a steady progression of larger to smaller rocks as they gradually eroded over time. However, they found that rocks of different sizes were distributed at random. They also found that the rocks were distributed in clear bands of debris across the glaciers' surfaces, with each marking the limit of separate and distinct flows of ice, indicating that each formed during a separate ice age.

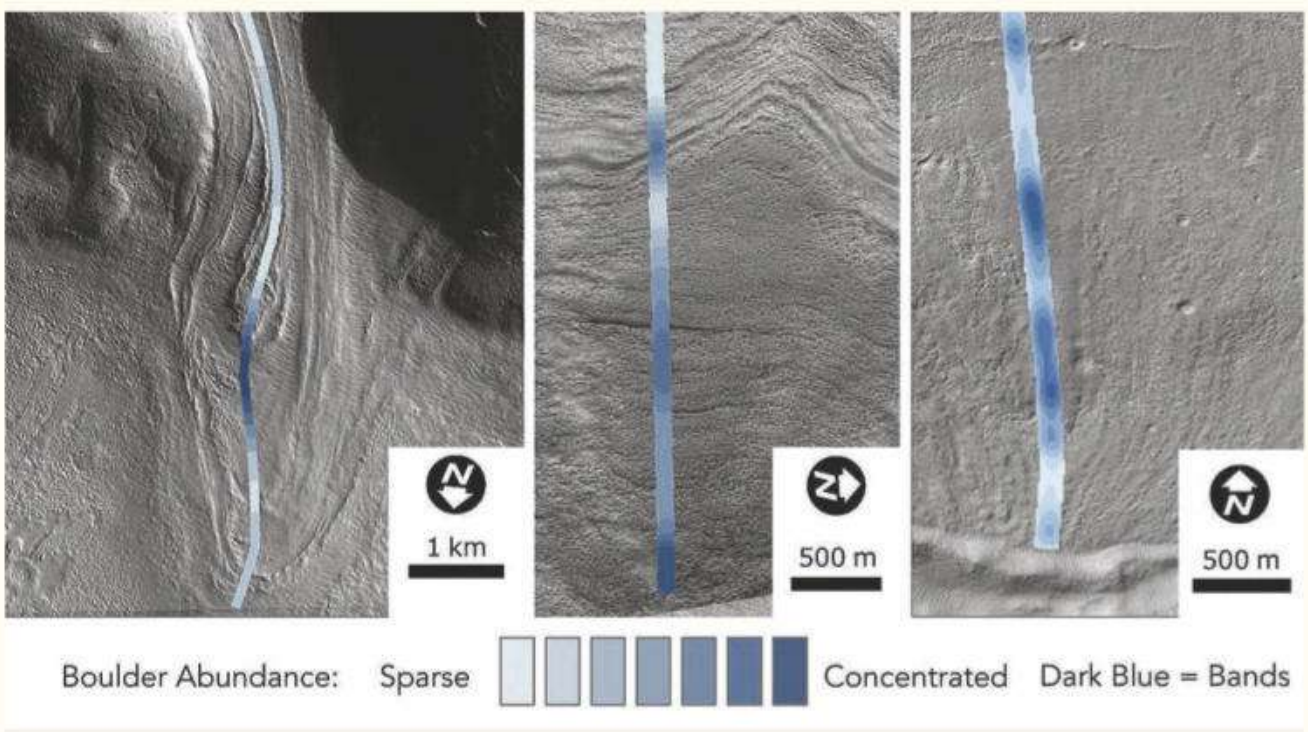
"These glaciers are little time capsules, capturing snapshots of what was blowing around in the Martian atmosphere," said Dr Joe Levy, a planetary geologist and assistant professor of geology at Colgate University.

"Now we know that we have access to hundreds of millions of years of Martian history without having to drill down deep through the crust – we can just take a hike along the surface."

Further examination of the glaciers could help scientists to figure out how the climate of Mars has changed over time – as well as what kind of rocks, gases, or even microbes might be trapped inside the ice.

The researchers have now begun to map the rest of the glaciers on the Red Planet's surface and hope to use an artificial intelligence system to count and analyse the rocks, to piece together a complete planetary history of Mars.

"There's a lot of work to be done figuring out the details of Martian climate history, including when and where it was warm enough and wet enough for there to be brines and liquid water," said Levy.



These images of glaciers on Mars show the distribution of boulders in the ice

MAXAR TECHNOLOGIES/DIGITAL GLOBE X2, JOE LEVY/COLGATE UNIVERSITY

In numbers

40 billion

The number of base pairs in the genome of the Australian lungfish, making it the longest ever to be sequenced. The human genome has just three billion base pairs.

8 per cent

The percentage of dangerous PM10 particles in Milan that are generated by cigarette smoke. The city has now introduced a ban on smoking within 10 metres of another person.

96 per cent

The amount saved on the carbon footprint generated by a web-conferencing call if video-streaming is turned off, as calculated by researchers at Purdue University, Indiana.

HEALTH

Scientists begin to untangle mechanism that causes IBS

Early work shows how antihistamines could be used to treat the condition

There are thought to be millions of people in the UK with irritable bowel syndrome (IBS), yet despite the large number of sufferers, little is known about the condition. According to the NHS, IBS is usually a lifelong problem and has no known cure, though changes in diet and some medicines can alleviate symptoms.

Now, a team of researchers at KU Leuven in Belgium have uncovered a mechanism behind the stomach pain and discomfort felt by IBS sufferers that could lead to potential new treatments using antihistamines.

The team's previous research demonstrated that blocking histamine – the compound that's produced by the body's immune system in response to an allergen – seemed to improve IBS symptoms.

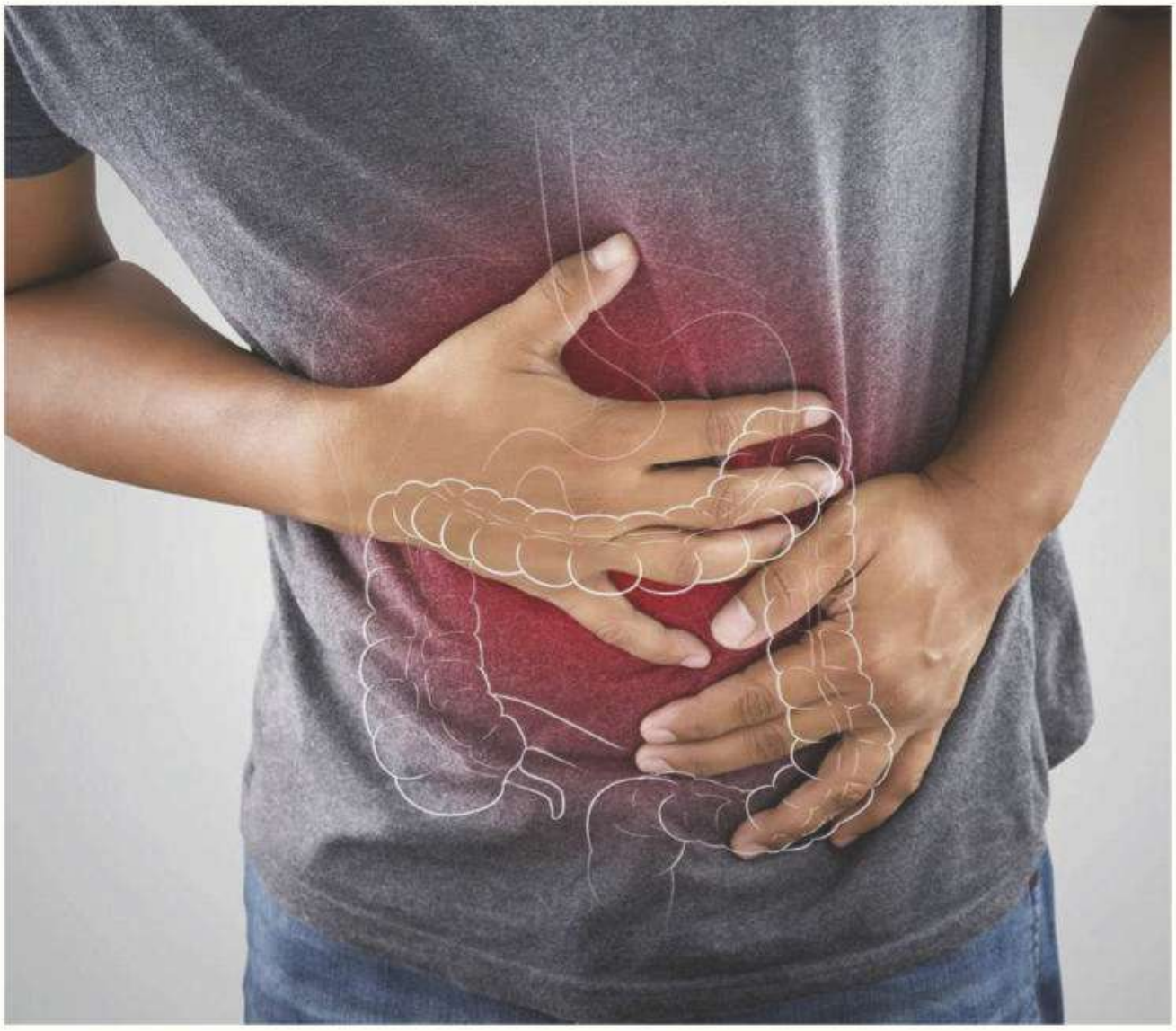
It's been established that people who have suffered with an gastrointestinal infection (GI) in the past, such as food poisoning, seem to be more likely to go on to suffer from IBS symptoms. The team hypothesised that this could be the consequence of the immune system becoming sensitive to any foods present in the gut when the infection was present. In other words, if some bad oysters gave you food poisoning once, they could then be a trigger for IBS in the future.

To test this, they took a group of mice and gave half of them a GI infection and then fed them all with an egg protein called ovalbumin. A few weeks after the infected mice had recovered, the team once again presented the whole group with the protein. The mice that were previously infected with the bug released histamine in their gut, while those that had not been infected showed no response. The scientists also noticed the activation of mast cells, which produce histamine. The infection had therefore triggered an immune response to the ovalbumin.

The team then went on to inject gluten, wheat, soy and cow's milk – which are known triggers for IBS – into the intestines of a small group of 12 human patients with IBS and saw a localised release of histamine in the intestine, just as they did with the mice. The researchers have now begun a larger clinical trial to investigate the effect of treating sufferers of IBS using antihistamines.

"This is further proof that the mechanism we have unravelled has clinical relevance. But knowing the mechanism that leads to mast cell activation is crucial, and will lead to novel therapies for these patients," said Boeckxstaens. "Mast cells release many more compounds and mediators than just histamine, so if you can block the activation of these cells, I believe you will have a much more efficient therapy."

> **"Unlike an allergic reaction, with IBS the production of histamine was localised within the intestine"**



SCIENCE PHOTO LIBRARY, GETTY IMAGES

ZOOLOGY

Genetic mutation gives snakes resistance to the venom of other snakes

Snake venom can pack a serious punch. In some species it contains toxic substances that affect the nerves (neurotoxins), which can kill small mammals in minutes and in some cases can even dispatch other snakes.

However, certain snake species are able to survive snake bites that would be deadly to others. A new study

> "It's an inventive mutation that's been completely missed until now"

by researchers at the University of Queensland, Australia, has discovered that this phenomenon is down to genetic mutations that allow their nerve receptors to repel the neurotoxins, similarly to the way the two positive sides of a magnet repel each other.

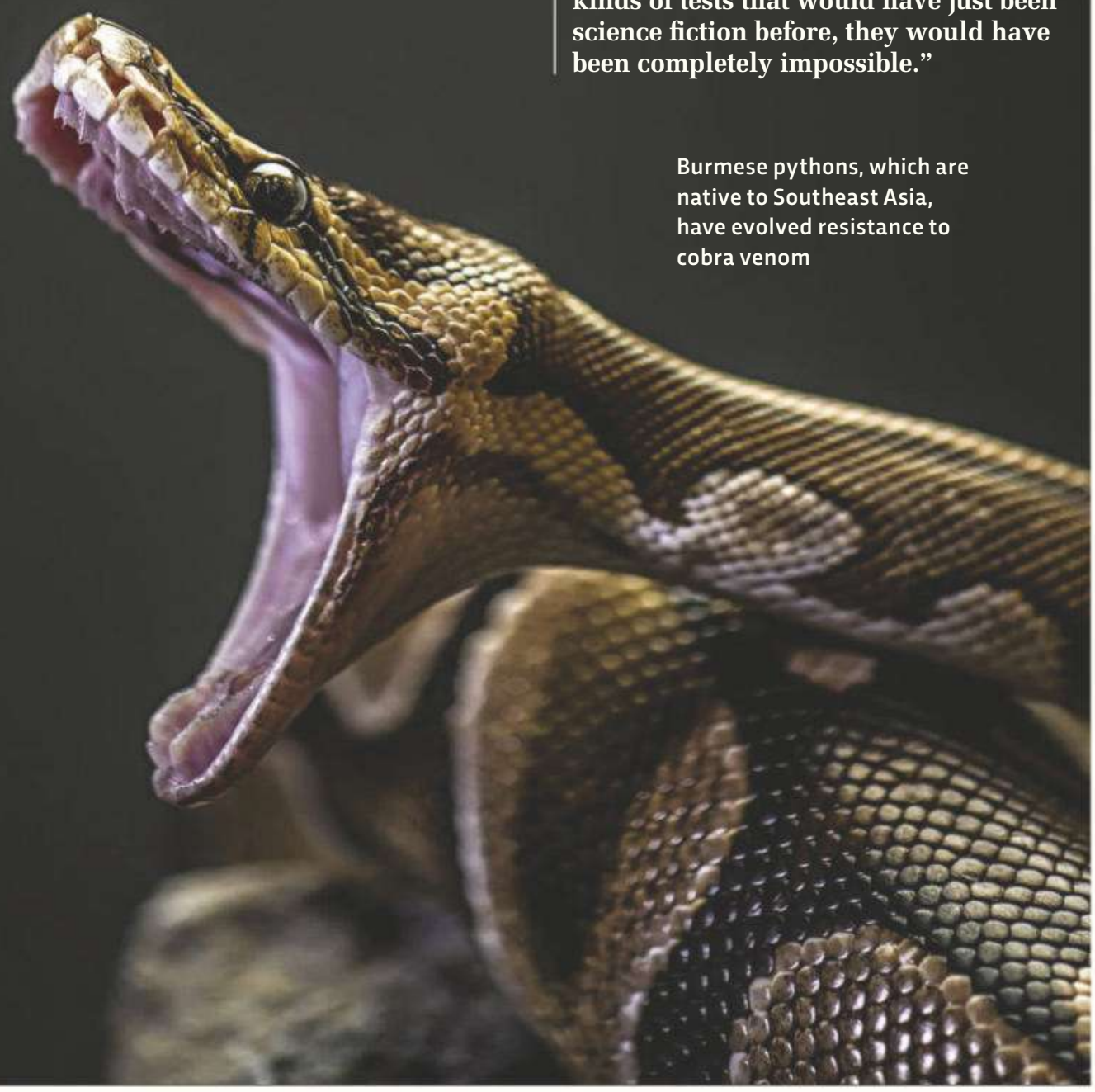
Snakes such as cobras (*Naja* species) and kraits (*Bungarus* species) that prey on other snakes possess neurotoxins with positively charged sites on their molecular surfaces. Such sites allow the venom to bind with target nerves that have negatively charged receptors, and therefore paralyse the snakes' prey.

However, the team found that some species, such as the Burmese python and the South African mole snake, which are both preyed upon by other snakes, have genetic mutations that mean their target nerve receptors are positively rather than negatively charged. As a result, their neurons repel the venom.

"It's an inventive genetic mutation and it's been completely missed until now. We've shown this trait has evolved at least 10 times in different species of snakes," said Dr Bryan Fry, an associate professor at the university's Toxin Evolution Lab.

The team made the discovery by developing artificial nerves with and without these specific mutations and then observing their interactions with venoms using cutting-edge biosensors at the Australian Biomolecular Interaction Facility (ABIF).

"There's some incredible technology at the ABIF allowing us to screen thousands of samples a day," Fry said. "That facility means we can do the kinds of tests that would have just been science fiction before, they would have been completely impossible."



Burmese pythons, which are native to Southeast Asia, have evolved resistance to cobra venom

BIOENGINEERING

Engineers create 'living materials' inspired by kombucha microbes

Kombucha – the trendy fermented drink beloved by health freaks and hipsters alike – has inspired researchers to grow a 'living material' capable of carrying out a range of tasks, such as detecting pollutants or purifying water.

Engineers from MIT and Imperial College London made the material using a SCOBY, or symbiotic culture of bacteria and yeast. Usually used as a mother culture for making fermented kombucha tea, in this instance it was used to produce cellulose embedded with enzymes that can perform a variety of functions.

Dubbed Syn-SCOBY, the material was made by combining a strain of laboratory yeast called *Saccharomyces cerevisiae* with a type of bacteria called *Komagataeibacter* that the team had isolated from a kombucha mother. The *Komagataeibacter* bacteria in the culture produced large quantities of tough cellulose that served as a scaffold to house the yeast and any enzymes it produced.

As the yeast is easily modified, the researchers were able to engineer it to do various things, such as produce enzymes that glow in the dark, or sense pollutants or pathogens in the environment.

"We foresee a future where diverse materials could be grown at home or in local production facilities, using biology rather than resource-intensive centralised manufacturing," said Dr Timothy Lu, an associate professor in MIT's electrical engineering and computer science department.

The team is now looking into using Syn-SCOBY for biomedical or food applications, such as engineering the yeast cells to produce antimicrobials, or proteins that could be eaten by humans.

ABOVE The bacteria in the Syn-SCOBY produce large amounts of strong cellulose that serves as a scaffold

RIGHT Tzu-Chieh Tang, one of the MIT researchers who helped develop the Syn-SCOBY

Scientist preparing small doses of LSD in a laboratory

CHENFU HSING, BRYCE VICKMAN, ZIJAY TANG, GETTY IMAGES X2

Mechanism behind LSD's therapeutic potential uncovered

A new study has identified why the drug causes sociable behaviour, which could lead to treatments for mental disorders

It has long been noted that small doses of LSD (lysergic acid diethylamide), can promote empathy and produce a feeling of a greater connection to the world in those who take it. But until now, the reason *why* this happened was unknown.

Now, researchers from McGill University in Canada have discovered one of the possible mechanisms that contributes to the drug's ability to produce these effects. The breakthrough could pave the way towards using the drug to treat mental health problems such as anxiety and alcohol-use disorder.

The researchers administered a low dose of LSD to a group of mice over a period of seven days and noticed that it led to an increase in their social interactions. Then, using optogenetics – a cutting-edge technique that allows specific areas of the brain to be activated and deactivated using light signals – they found that the increased sociability occurred because LSD activates specific areas of the brain's prefrontal cortex called the serotonin 5-HT2A receptors and AMPA receptors.

Now, the researchers are keen to test the effectiveness of LSD in treating mice selectively bred to display behaviours similar to those seen in people with social anxiety disorders or autism.

They then hope to eventually explore whether microdoses of LSD might have a similar effect in humans, and whether it could also be a viable and safe therapeutic option.

"Social interaction is a fundamental characteristic of human behaviour," said co-lead researcher Dr Gabriella Gobbi, a professor in the department of psychiatry at McGill University.

"These hallucinogenic compounds, which, at low doses, are able to increase sociability, may help us to better understand the pharmacology and neurobiology of social behaviour and, ultimately, to develop and discover novel and safer drugs for mental disorders," she added.

WARNING: LSD is a Class A drug according to UK law. Anyone caught in possession of such substances will face up to seven years in prison, an unlimited fine, or both. More information and support for those affected by substance abuse problems can be found at bit.ly/drug_support

MEDICINE

Transplants of retinal cells could treat blindness

Experiments showed that the transplants survived for three months and started to function

Researchers have successfully transplanted retinal cells into monkeys' eyes, giving hope for this method as a treatment for blindness.

Over 200 million people worldwide are affected by vision loss due to degeneration of a layer of cells in the eye called the retinal pigment epithelium (RPE).

In this proof-of-concept study, an international group of scientists took stem cells from the donated eyes of human adults and turned them into retinal cells. They then transplanted these cells into the eyes of monkeys, where they survived for three months with no serious side effects, such as attack from the immune system or light sensitivity.

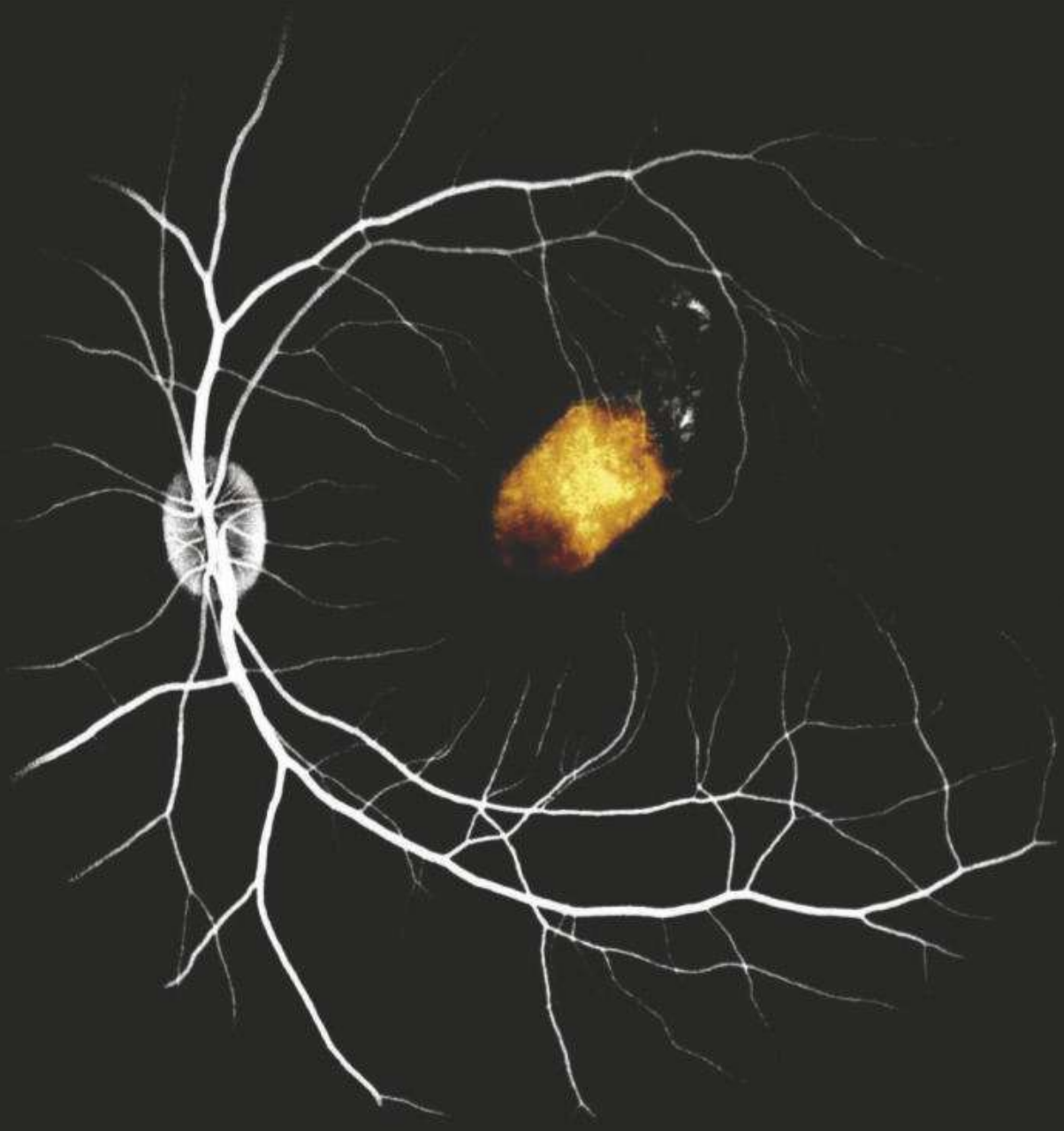
What's more, the cells started to take over some of the function of the monkeys' RPE, and didn't cause any retinal scarring.

"Human cadaver donor-derived cells can be safely transplanted underneath the retina and replace host function, and therefore may be a promising source for rescuing vision in patients with retina diseases," said Dr Timothy Blenkinsop, assistant professor in cell, developmental and regenerative biology at the Icahn School of Medicine, New York. "The results of this study suggest human adult donor RPE is safe to transplant, strengthening the argument for human clinical trials for treating retina disease."

Using stem cells could provide an unlimited source of transplants, and could ensure that the transplants are matched to the recipients, the researchers say.

This study shows that it is feasible that RPE transplants derived from stem cells could be a viable treatment for visual impairment. However, further experiments are needed before this treatment will become available.

The researchers say that next, they need to give the transplants to diseased monkeys and test whether it actually restores their sight. Following that, this method will then be tested in human patients.



"The results of this study strengthen the argument for human clinical trials for treating retina disease"

Retinal pigment epithelial cell implant (yellow section) transplanted beneath the retina of a monkey

XINYI SU, L SOUSA ILLUSTRATIONS: KYLE SMART

NATURE

Electric eels will team up to zap their prey

Electric eels have been recorded hunting in groups for the first time

It's not just the Avengers who work best as a team: it turns out that electric eels also assemble to defeat their foes. Or at least catch their next meal.

While monitoring wildlife in the Amazon River, scientists from the Smithsonian National Museum of Natural History discovered groups of up to 10 eels may form a pack to attack tetras. After herding the small fish into a tightly packed ball, the eels then deliver a synchronised high-voltage strike.

"This is an extraordinary discovery," said Dr David de Santana, lead author of the new study. "Nothing like this has ever been documented in electric eels. Hunting in groups is pretty common among mammals, but it's actually quite rare in fishes. There are only nine other species of fish known to do this, which makes this finding really special."

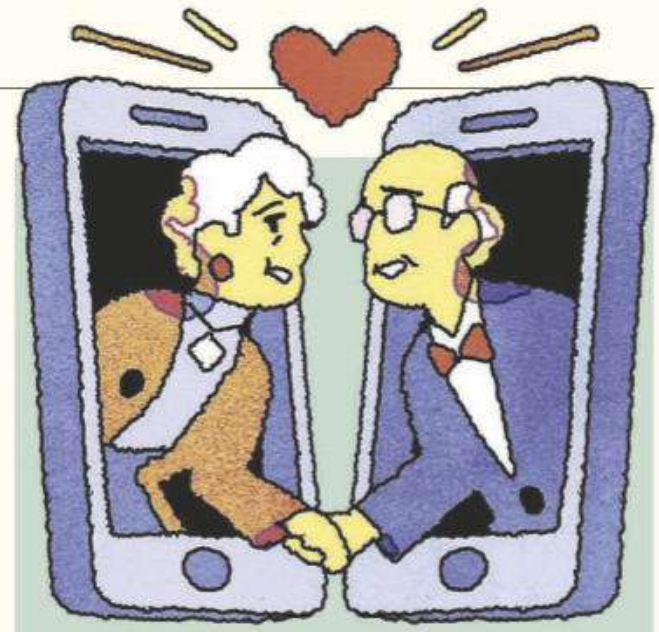
Electric eels – which are actually a type of knifefish, not actual eels – are capable of discharging up to 860 volts of electricity. They produce this charge through a specialised organ made up of cells known as electrocytes. These cells (each carrying less than 100 millivolts), link together to form a biological battery.

"In theory, if 10 eels discharged at the same time, they could be producing up to 8,600 volts of electricity," said de Santana. "That's around the same voltage needed to power 100 light bulbs."

But what would happen if an eel shocked a human? As de Santana knows first-hand, although the initial shock lasts for a mere two-thousandths of a second, it can still prompt a muscle spasm capable of knocking you off your feet.

It was previously believed that there was only one species of electric eel, but de Santana and his colleagues have unearthed an extra two varieties – alongside 85 new species of other electrical fish.

But while only recently discovered, de Santana fears these eels may soon come under threat due to deforestation and climate change. "Electric eels aren't in immediate danger, but their habitats and ecosystems are under immense pressure," he explained. "This paper is an example of how much we still don't know, how many organisms whose life histories we don't yet understand."



ONLINE DATERS

Swiss researchers have found that couples who met through dating apps were more likely to move in together, and more likely to want to have children, than couples who hooked up in more traditional ways.

THE SUPERFIT

We all know we should be moving a bit more to improve our health. Now, a study at the University of Oxford has found that the benefits for the cardiovascular system keep piling up the more activity we get, with the most active people reaping the most gains.

Good month

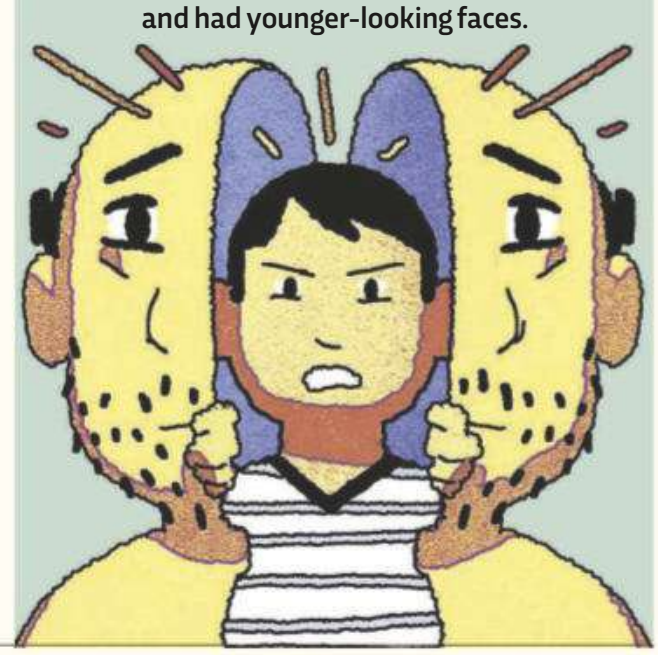
Bad month

ANGRY GAMERS

Prone to rage-quitting when gaming? Maybe rethink your approach. *FIFA 19* players that were shown positive video clips before playing scored more goals than those shown negative, angry clips, Stanford University researchers have found.

NAUGHTY CHILDREN

Kids who are impulsive, aggressive and inattentive have poorer health in later life. A study at Duke University followed 1,000 New Zealanders from birth to age 45. Those rated as having more self-control as children showed slower signs of ageing in their organs, and had younger-looking faces.



NASA, ALAMY ILLUSTRATIONS: CATHAL DUANE

DR ADAM POWELL
Research associate in religion and medical humanities

Horizons

Why some people say they can 'hear the dead'

According to new research, spiritualist mediums might be more prone to immersive mental activities and unusual auditory experiences early in life

YOUR WORK FOCUSES ON A QUALITY CALLED 'ABSORPTION'. WHAT EXACTLY IS IT?

Absorption has to do with a tendency to get lost in your own thoughts, become immersed in mental imagery, or become lost in an altered state of consciousness. It's been found that high absorption rates predict things like mystical experiences among those who use psychedelics. So, among a group of people who took MDMA, those who scored higher on absorption would more likely report a mystical experience. And it's correlated with a lot of things, like measures of dissociation and openness to experiences.

WHAT MADE YOU THINK THAT ABSORPTION MIGHT INFLUENCE SPIRITUALISM?

Academics have spent years trying to understand why people have religious experiences. Why do some say, "I heard God's voice" or "I heard the spirit speak to me"? Anthropologist Tanya Luhrmann has really championed the idea that absorption, and the scale used to measure it, helps identify those who have the most vivid, frequent religious experiences. We wanted to discover whether clairaudient mediums – mediums who said they had received auditory communications from spirits – have a proclivity for these experiences. And also, how they're experiencing them. Somewhat surprisingly, existing work doesn't go into detail about what it's like to hear the dead, although there are discussions around whether it's real, related to parapsychology, or whether it's similar to hallucinations among psychiatric patients.

WHAT WERE YOUR KEY FINDINGS?

We found that spiritualists did score higher on levels of absorption and proneness to auditory hallucinations, compared to a control group. Many of the spiritualists had early experiences, about 20 per cent for as long as they can remember, while over 70 per cent had unexplained experiences before encountering spiritualism that they now deem spiritual. Also, spiritualists were, figuratively speaking, off the charts in terms of personal identity and really didn't care much about how people saw them, which corresponds well with spirituality being a subjective, personal issue.

DID YOU FIND OUT WHAT IT'S LIKE TO EXPERIENCE ONE OF THESE EVENTS?

We're still engaged in one-on-one interviews with spiritualists, but for instance, 65 per cent reported these experiences occur inside their head. So even though it's reported as auditory, the vast majority don't mean it's heard

GETTY IMAGES

"Depending on the survey, anywhere from 5 to 15 per cent of the population hears voices in their lifetime"

outside their head. About 30 per cent reported the experiences both inside and outside the head.

We also found these communications – and this is important if you're comparing them with the complex hallucinations reported by schizophrenic patients – are experienced in a specific and simple way. So, it may be just an image or a word they see, kind of flashing, almost like it's a neon light.

SO, IS IT SEPARATE TO SOMETHING LIKE SCHIZOPHRENIA? OR POTENTIALLY PART OF THE SAME SPECTRUM?

Most of our research is corroborating the idea that voice-hearing is on a spectrum. Depending on the survey, anywhere from 5 to 15 per cent of the general population hears voices in their lifetime, and if you broaden that to any kind of hallucinatory experience, it increases to 30 to 60 per cent. There are scenarios in which this is well accepted and not viewed as a pathological problem. For instance, hearing the voice of a deceased relative while grieving is common, but it's more accepted, socially and culturally. They're in the grieving period, that frame of mind. And somewhere on there, spiritualists fall alongside people who hear God's voice, for instance.

CAN SPIRITUALISTS LEARN TO CONTROL THESE AUDITORY EXPERIENCES?

Generally speaking, yes. Spiritualists call it an ability, a muscle [they can] train to grow stronger. But it's a muscle they already have. Some can influence things by talking back to the voice, saying, "I'm busy, come back later", and the voice will obey, but also influence the frequency of experiences. Some would say, "I've honed my skills and now I have daily experiences, but only when I want them".

DOES BEING ABLE TO CONTROL THE VOICE MAKE IT A MORE POSITIVE EXPERIENCE, AS OPPOSED TO SOMETHING MORE DISTRESSING AND NON-CONTROLLABLE?

That's a really good question and one theory we're working with is precisely that. If something is perceived as within your control, it's less threatening. It may be that in Western societies that have historically emphasised individual agency and choice, it's a threatening realisation, if these experiences are viewed as intrusive and undesired. The other theory is that once someone embraces spiritualism and identifies as a medium, they view these communications as not intended for them, but a third party. One researcher postulated that, if these experiences are meant for someone else, you needn't be concerned about the content, tone or temperament of the spirit. Most spiritualists say as soon as they relay the message, they forget it. And often, they can't recall the bulk of their experiences as a practising medium, as they weren't meant for them. Compare that to someone with schizophrenia. Schizophrenics rarely, if ever, say those voices are directed at someone else; they're absolutely directed at them. This could be disconcerting in itself.

WHAT KIND OF POSSIBILITIES DOES YOUR RESEARCH OPEN UP?

We're taking it into conversations about mental health, but don't want to claim these experiences are the same as other hallucinatory experiences. Instead, we're addressing questions like: why do spiritualists who have these experiences feel comforted by the voices, when roughly 60 per cent of them initially experience the voices in a traumatic situation? That's obviously very different from people with severe mental illness who hear voices. We also have a cognitive neuroscience study coming out that used fMRI brain scans and a study of similar experiences that occur as you're falling asleep or waking up; quite a few spiritualists reported their earliest experiences taking place in the borders of sleep.

COULD THAT BE LINKED TO SOMETHING LIKE SLEEP PARALYSIS?

Absolutely. Generally, we'd call that hypnagogia, when someone's in that liminal state of consciousness. People have more hallucinatory experiences in that state and you can increase frequency through sleep deprivation or changing sleep schedules. It's even being reported now because of the pandemic. People aren't releasing as much energy during the day and their sleep is more disrupted, so we're seeing an increase in these experiences. But in mental health research and with the religious experience side of things, no one is really talking about cases of hypnagogia that end up being deemed spiritually significant.

DR ADAM POWELL

Adam is the lead researcher in Durham University's Hearing the Voice project, and is the COFUND junior research fellow in the department of theology and religion. Interviewed by freelance science writer Holly Spanner.

Mojave Air and Space Port, California

1

2

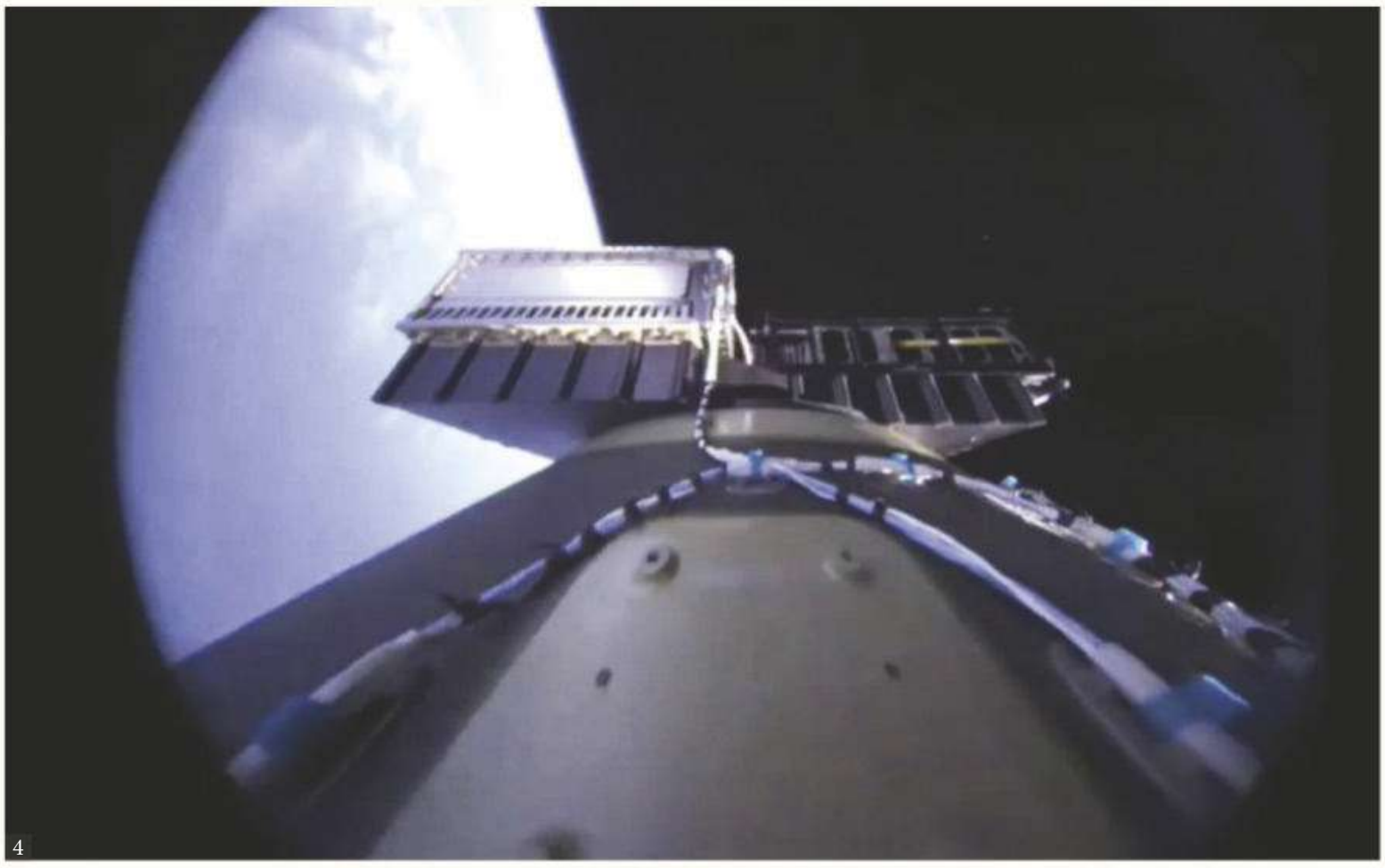
SPACE

Virgin air-launched rocket successfully carries 10 tiny 'CubeSat' satellites into orbit

On the morning of 17 January, Virgin Orbit's LauncherOne rocket made its first successful voyage into orbit. The rocket was launched from under the wing of a jet aircraft, rather than a traditional launch pad on the ground, from Mojave Air and Space Port in California. It is the first orbital class, air-launched, liquid-fuelled rocket to reach space.

VIRGIN ORBIT X4

3



4

1. The satellites were selected by NASA's Launch Services Program as part of the CubeSat Launch Initiative. Nine out of 10 of the CubeSats were designed, built and tested by universities across the US. The CubeSats will carry out studies such as weather readings, debris analysis and effects of radiation.

2. LauncherOne was taken into the air by Virgin Orbit's carrier aircraft, a customised Boeing 747-400 dubbed 'Cosmic Girl'.

3. After a smooth release from the aircraft at a height of about 10,000m, the rocket ignited and powered itself into orbit.

4. Once in its target orbit, the rocket deployed the CubeSats. The satellites are fitted with cameras, allowing them to beam back pictures as they travel around the Earth.

Our Universe may contain many other universes, hidden within black holes

SPACE

Black holes and the multiverse could account for all dark matter

Black holes that formed in the early moments of the Universe could explain dark matter, physicists claim. They also say that some of these black holes could contain 'baby universes' that will never know we exist.

In the beginning, the Universe was incredibly hot and dense – so much so that a random local fluctuation that increased the density of an area by only 50 per cent would be enough to spark gravitational collapse into a black hole. Unlike the black holes we see in our modern Universe, the hypothetical 'primordial' black holes created at this time didn't form from a collapsing star, which means they could have a wide range of masses, including extremely small ones.

Shortly after the Big Bang, the expansion of the Universe accelerated. This phase of faster-than-light expansion is known as inflation. During this period, it is theoretically possible for bubbles of 'false vacuum' to form – that is, bubbles of space that have a higher energy than the space that surrounds them. False vacuum bubbles are 'metastable', meaning that they are more or less stable, but, like a football balanced at the top of a hill, a small kick can knock them into a more stable, lower-energy state.

There is a critical size that determines what becomes of these false vacuum bubbles. If, when they pop into existence, they are smaller than this size, they will collapse. The energy they release in such a small volume will then trigger the formation of a primordial black hole. If the false vacuum bubble is bigger than the critical size, the researchers say, the bubble will rapidly expand, then suddenly contract and collapse into a different type of primordial black hole. However, though it would appear to be a black hole to us, an observer on the inside of the black hole would see themselves in an expanding 'baby universe'.

Since no light can escape from a black hole, anything inside this baby universe would never know that our Universe exists. This would mean that our cosmos existed as part of a multiverse, and dark matter – the mysterious material that makes up about 85 per cent of all matter in the Universe – is the result of the gravity of these baby universes.

The researchers say that the Hyper Suprime-Cam on the Subaru Telescope in Hawaii, while observing the Andromeda Galaxy, spotted an event consistent with what they would expect primordial black holes to look like. The team has begun a deeper search for primordial black holes, to prove whether or not this multiverse theory could solve the problem of dark matter.

They did what?

Baboons' accents analysed

WHAT DID THEY DO?
Researchers at the German Primate Center listened in on the low frequency grunts that male Guinea baboons use to communicate with one another and studied their acoustic structure.

WHY DID THEY DO THAT?
They wanted to study the evolution of vocal learning; essentially, the ability to imitate sounds that allows humans to learn new languages even into old age.

WHAT DID THEY FIND?
Baboons in different social groups shared similarities in their grunts, much like accents in human languages, suggesting a degree of a phenomenon known as 'vocal accommodation'.

"People do this also: they often involuntarily adjust the tempo or their pitch to be more similar to that of the person you are talking to," said lead researcher Prof Julia Fischer. "Such effects seem to be shared between non-human primates and humans. But it is a far cry from learning to say the first word – or master an entire language."

ALAMY X2, GETTY IMAGES

At 15 to 18 metres in length, megalodon is thought to be the largest shark to ever exist

PALAEONTOLOGY

Megalodon sharks ate their siblings in the womb

The extinct sharks gave birth to huge babies that were bigger than humans

Just when you thought megalodon sharks couldn't get any more terrifying, new research suggests they practised pre-birth cannibalism.

According to a study on the extinct animals by palaeobiologists at Chicago's DePaul University, it's likely that embryonic megalodon sharks fed on unhatched eggs in their mother's womb. In short, even before preying on other species in the ocean, megalodons feasted on their unborn siblings first.

This finding was part of a larger piece of research examining the reproductive biology and growth of the shark. Using CT scanning techniques on vertebrae fossils of a megalodon, scientists were able to identify 'growth bands', similar to tree rings, to reveal how much the shark grew each year.

Not only did the megalodon's growth bands suggest that the nine-metre predator died aged 46, but they also revealed the shark was a massive two metres in length at birth. That's a baby bigger than Dwayne 'The Rock' Johnson. The gigantic size of the shark at birth indicated to scientists that, just like present-day lamniform sharks (a large group that includes great white sharks and mako sharks), embryonic megalodons fed on eggs in the womb. The researchers believe this form of cannibalism, known as oophagy, was needed to produce sharks that were already big enough to compete with fellow predators fresh out of the womb.

"As one of the largest carnivores that ever existed on Earth, deciphering such growth parameters of the megalodon is critical to understanding the role large carnivores play in the context of the evolution of marine ecosystems," said Prof Kenshu Shimada, lead author of the study.

Megalodon sharks, which lived worldwide roughly 15 to 3.6 million years ago, reached at least 15 metres in length – at least three times the length of today's average great white shark.

Positioned at the top of its food chain, it's estimated that the megalodon had a jaw measuring 2.7 x 3.4 metres – big enough to fit two adult humans.

The sharks are now extinct, and are theorised to have been killed off when Earth entered a phase of global cooling. However, the exact reason behind the megalodon's demise is yet to be confirmed.

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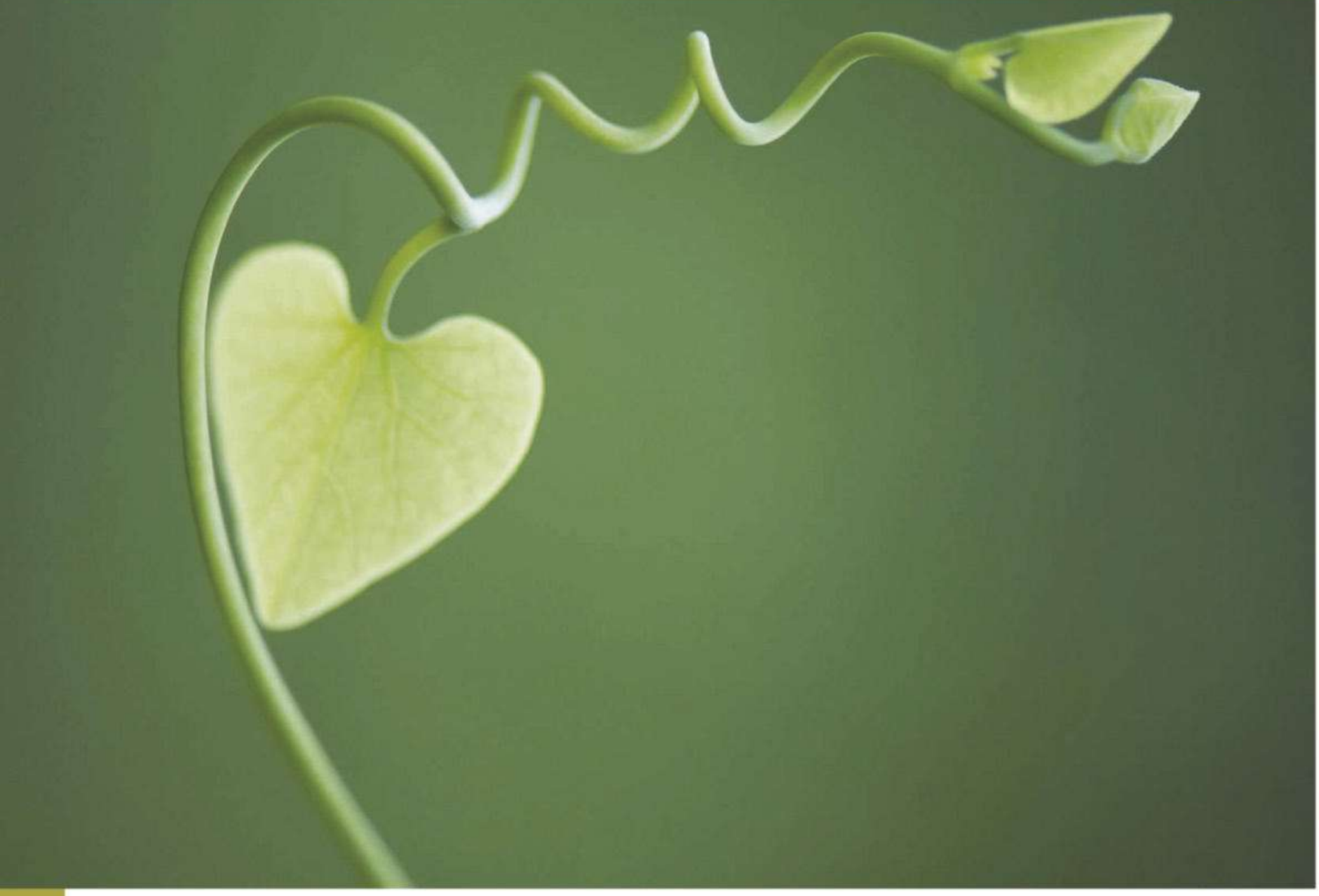
REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Plant consciousness | Gene editing | COVID in 2022



REVIEW

PLANTS: ARE THEY CONSCIOUS?

The idea of plants being capable of making conscious decisions is a controversial one, but a new study involving climbing French beans suggests the concept may be beginning to take root

"If we separate our biases away from thinking that some features only belong to us, then we can move the field forward much faster"

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WHAT WAS THE EXPERIMENT?

Researchers based at the Minimal Intelligence Lab at the University of Murcia, Spain, and the Rotman Institute of Philosophy in London, Canada, placed 20 potted French bean plants in the centre of cylindrical booths. The plants were either alone, or accompanied by a garden cane planted into the ground 30 centimetres away.

The scientists then used time-lapse photography to track the movements of the plants until the tip of the shoots made contact with the canes. They found that the shoots would grow along more predictable paths in the presence of the canes, almost as if they could sense them in their vicinity and adjust their growth patterns as a response.

DOES THIS DEMONSTRATE CONSCIOUS INTENT?

Some plants respond to their environments by, for example, curling their leaves up when touched, or enclosing and digesting their prey in their leaves. The basic mechanisms of these responses have been well studied, but addressing the more philosophical questions, such as whether or not the plants 'intelligently choose' to execute such actions, is a much more recent idea.

While not claiming that the experiment proves once and for all that plants can and do act with conscious intent, the Rotman Institute of Philosophy's Dr Vicente Raja, one of the authors of the study, says it does show that the beans in the experiment were doing more than simply responding to external stimuli.

"It is one thing to react to a stimulus, such as light, it is another thing to perceive an object," he says. "If the movement of plants is controlled and affected by objects in their vicinity, then we are talking about more complex behaviours, not reactions, and we should be able to identify similar cognitive signatures to those we observe in humans and some animals."

WHERE COULD PLANT CONSCIOUSNESS ARISE FROM?

Plant neurobiology was officially established as an area of research in 2006. Its proponents draw parallels between the pathways of electrical signalling found in plants and the nervous system found in animals, to argue that plants are capable of acting in a purposeful manner.

Plants use electrical signals in two ways. First, to regulate the distribution of charged particles (ions) across their various membranes. For example, a plant's leaf might curl up because a movement of ions triggered the transport of water out of its cells, which caused it to change shape. Second, to relay long-distance messages from one part of the plant to another. For example, an insect bite on one leaf might trigger defence responses in distant leaves. Both actions can appear like a plant is choosing to react to a stimulus.

"Only in the last decade is when we have been associating animals with sentience, answering these questions takes time. If we separate our biases away from thinking that some features only belong to us, then we can move the field forward much faster," says Dr Paco Calvo, director of the Minimal Intelligence Lab at the University of Murcia and co-author

BELOW According to the new study, plants may have more complex behaviours than we've previously given them credit for

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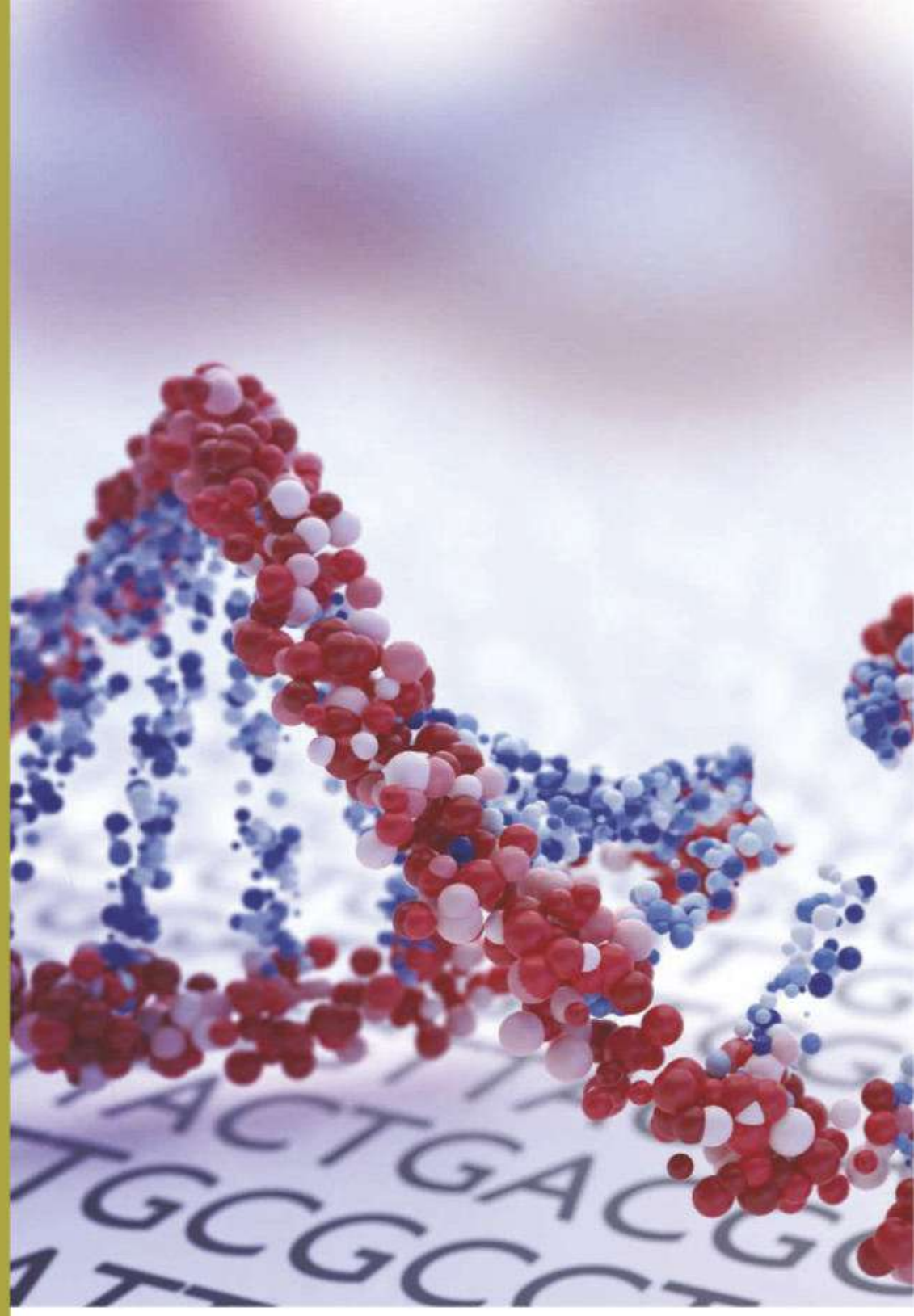


“There’s absolutely no advantage to the plant to have a highly developed nervous system”

of the study. “I am happy to be disproved, but we need to be open to possibilities.”

WHAT DO THE CRITICS SAY?

Some researchers argue that these responses are merely genetically encoded and have been fine-tuned to give the appearance of intentional action, thanks to countless generations of natural selection.

In a paper titled ‘Plants neither possess nor require consciousness’, published in 2019, Prof Lincoln Taiz, a botanist at the University of California, Santa Cruz, dismissed the idea of plants having features such as consciousness and cognition on the grounds that they simply don’t have the necessary structural, organisational and functional complexity that the animal brain had to evolve before consciousness could emerge.

“The biggest danger of anthropomorphising plants in research is that it undermines the objectivity of the researcher,” Taiz says. “What we’ve seen is that plants and animals evolved very different life strategies. The brain is a very expensive organ, and there’s absolutely no advantage to the plant to have a highly developed nervous system.”

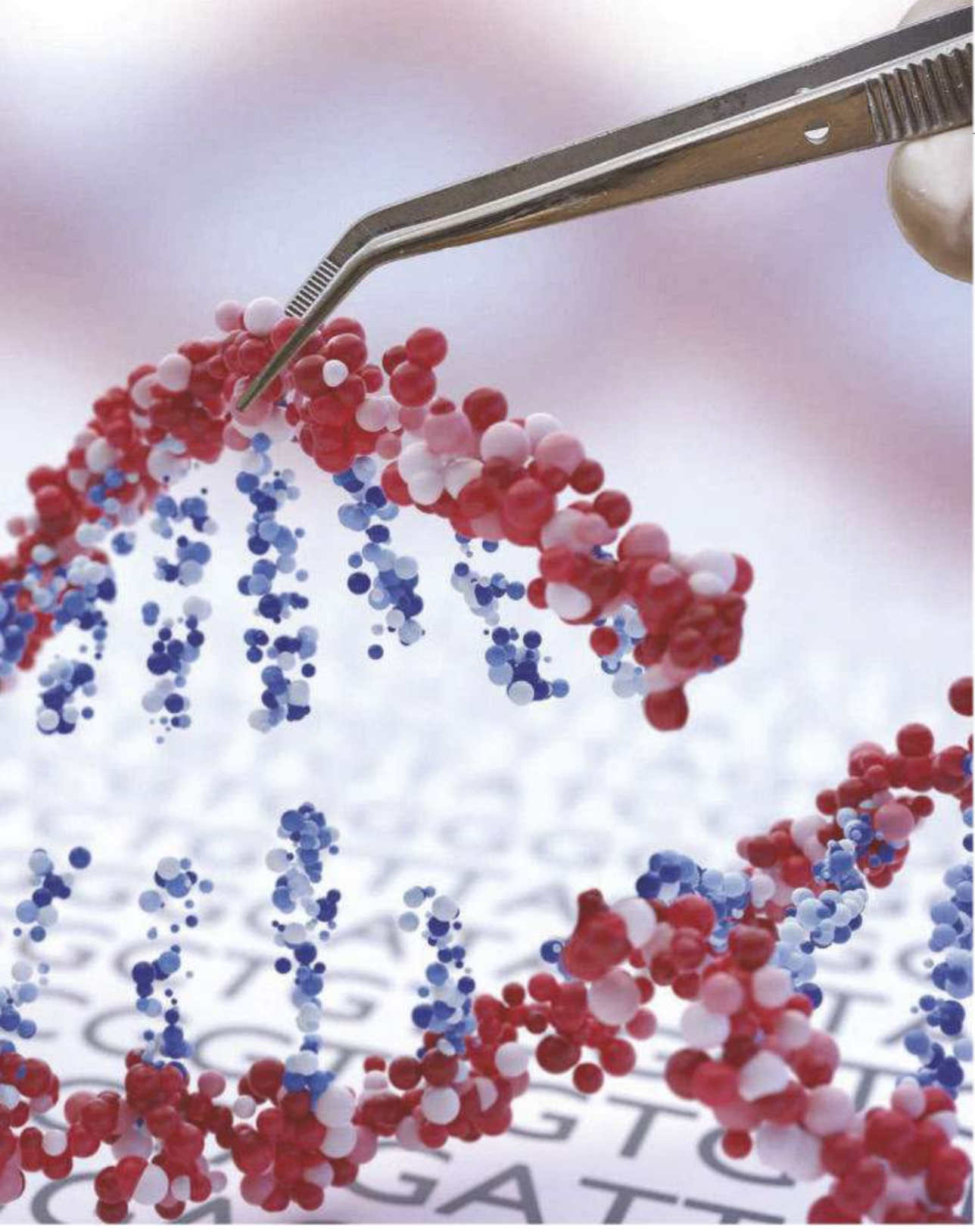
by EFRAÍN RIVERA-SERRANO
Efraín is a science writer with a background in virology and cell biology.

ANALYSIS

GENE EDITING: SHOULD LIVESTOCK AND CROPS BE GENETICALLY ENGINEERED IN THE UK?

The genetically modified food debate has been reignited after the UK government announced plans to consider loosening regulation on GM crops and animals

This year, in early January, a consultation was launched that asks whether organisms produced by genetic engineering should continue to be classified as genetically modified, if the organisms could have been developed using traditional breeding methods.



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ABOVE The differences between gene editing and gene modification are at the heart of potential changes to regulation

The consultation is especially focused on gene editing, also known as genome editing, a technology that allows scientists to add, remove or alter an organism's DNA. Unlike older types of 'transgenic' genetic modification, this process doesn't introduce foreign DNA into the gene. In a speech launching the consultation, Environment Secretary George Eustice said gene editing raises "far fewer ethical or biological concerns" than transgenic modification and "respects the rules of nature".

In 2018, the European Court of Justice ruled that gene-edited crops should be considered the same as other genetically modified crops under EU law, a ruling Eustice called "flawed and stifling to scientific progress".

Prime Minister Boris Johnson shares a similar view. In 2019 he pledged to "liberate the UK's extraordinary bioscience sector from anti-genetic-modification rules".

Gene editing is a relatively new and fast-evolving technology. The first type of gene editing, using CRISPR/Cas9, was only developed in 2012 (the two women that developed it won last year's Nobel Prize in Chemistry). Views on regulating the use of gene editing in producing genetically modified animals or crops have generally fallen into two camps, says Prof Katherine Denby from the University of York, who works on new ways to improve crops using tools such as gene editing.

The first camp argues that as gene-edited crops or livestock could have arisen through traditional breeding processes, they should not be classed as genetically modified organisms, meaning they wouldn't be subject to genetic modification regulations.

The second camp holds that any organism made through gene editing should be regulated as a genetically modified organism, regardless of whether the final product could have been made using traditional breeding. Countries such as the US, Australia and Japan have taken the former, more relaxed, approach, while the EU has taken the latter, more stringent one.

GENE MACHINE

Current UK regulations mean gene-edited crops can technically come to market, but the regulatory process is both lengthy and extremely costly, says Denby.

"It's really prohibiting the development of products, both crops and genome-edited livestock, just because of that cost," she says. This, in turn, is prohibiting the development of traits that are for public good, such as disease resistance, she says.

For example, her own work aims to replicate the disease resistance found in older and wild relatives of lettuce in more modern varieties, a process that will go many times faster using gene editing rather than traditional breeding.

But other scientists are more sceptical about the benefits that gene editing can bring and are concerned about its potential dangers.

"This technology comes with innate risks to alter the genetic composition, the patterns of gene function," says Dr Michael Antoniou, head of the gene expression and therapy group at King's College London. "In doing so you change the plant's biochemistry."

Antoniou says gene editing is not as highly precise as is often claimed and can bring about unintended mutations. "Worryingly, those who are developing gene-edited crops and foods are ignoring the risks," he says.

For instance, gene editing could run the risk of producing novel toxins or allergens, or increasing the levels of pre-existing toxins and allergens, especially in plants, he says.

"Without strict safety checks, it's possible that crops that are potentially harmful could enter the ➤

A farmer holds gene-edited corn that was produced on a farm in Minnesota. Regulations on gene-edited crops are less stringent in the US than in the EU

marketplace unlabelled and would therefore also be difficult to trace if any adverse outcomes were to be found," he adds.

In Antoniou's view, gene editing is "unquestionably" a genetic modification procedure and should continue being regulated in the UK as it is in the EU.

But many scientists argue that gene editing is crucial to supporting a more sustainable food system.

"Genome editing is already used in medicine and has immense potential for tackling major agricultural challenges related to food security, climate change and sustainability," says Prof Denis Murphy from the University of South Wales.

Denby agrees and says gene editing can play a part in making the UK's food system more sustainable, healthy and affordable, while admitting it's "not going to be a magic bullet".

But for Antoniou the focus really needs to be on the agricultural system as a whole, rather than improving individual crops and seeds.

Gareth Morgan, head of farming and land use policy at the Soil Association, has called gene editing a "sticking plaster" that diverts vital investment and attention from other more effective solutions.

"The focus needs to be on how to restore exhausted soils, improve diversity in cropping, integrate livestock into rotations and reduce dependence on synthetic nitrogen and pesticides," he says. "We want to see immediate progress in these areas rather than using Brexit to pursue a deregulatory agenda for genetic modification."

—

by **JOCELYN TIMPERLEY**

Jocelyn is a freelance climate journalist.

COMMENT

COVID-19 IN 2022: IS THERE HOPE FOR A BETTER TOMORROW?

Despite the doom and gloom of the pandemic, light remains at the end of the tunnel. But what can we realistically hope for in 2022?

The year 2020 is likely to live in our memories as the year COVID-19 brought the world to a standstill. Many are hesitant to hope for a more normal 2021, choosing to tentatively take life one day at a time as our future remains uncertain. But how does the world appear if we cast our eyes forward to 2022?

Although the world has experienced pandemics in the past, the closest example we have to a blueprint would be the severe acute respiratory syndrome (SARS) epidemic. This was a coronavirus that cost over 770 lives, largely in eastern Asia, during the early 2000s. But after complications cropped up in animal trials for a SARS vaccine and the virus died out in humans, research funding dried up. Little progress was made into coronavirus vaccine research.

Now, with multiple COVID-19 vaccines available and more on the horizon, life post-vaccine is imminent for those in countries that can afford it. But the dangers of vaccine nationalism may mean that poorer countries will go unvaccinated until 2022, 2023 or beyond, by which time the threat of new variants – given the opportunity to spread and potentially be resistant to current vaccines – is likely to grow.

Although Moderna has confirmed its vaccine is still effective against the new variants that have emerged so far, this news will make little immediate difference to the Global South, as all Moderna's vaccines for 2021 have been bought by richer countries. Despite the vaccines preventing severe disease, it's still left to be seen if they reduce transmission and how long immunity will last; some experts believe annual vaccinations may be necessary. So for those who can't be vaccinated and who exhibit different responses to illness, ongoing research into multiple therapeutics, such as antivirals and antibodies, could be life-saving.

LONG ROAD

While our bodies are capable of some immune response to the virus, assuming that we'll eventually 'get used' to COVID-19 is a deadly gamble – not dissimilar to

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“The danger of vaccine nationalism may mean that poorer countries will go unvaccinated until 2022, 2023 or beyond”

the ‘herd immunity without vaccination’ suggestions that prevailed early in the pandemic and proved to be harmful. Likewise, while there are other human coronaviruses that cause colds, a comparison with COVID-19 seems unhelpful as research has shown COVID-19 infects both the upper and lower respiratory tract. Also, whereas life often returns to normal after recovering from a cold or the flu, the ‘long-COVID’ phenomenon has seen many continue to suffer with multiple organ damage, fatigue, muscle aches and difficulty breathing, for months after the initial infection. Even 15 years after the SARS outbreak, a follow-up study found that many are still experiencing reduced lung-diffusion capacity.

ABOVE Global access to COVID-19 vaccines is imperative to reduce the chances of outbreaks of new variants

To reduce the number of strains emerging, a zero-COVID strategy is the best course of action: by limiting community transmission. Even if a more harmful strain were to evolve, it would eventually die out as SARS did. This can be achieved through a cocktail of interventions, like maintaining hand hygiene, wearing masks, a functioning test-trace-isolate system, government support (such as financial remittance during quarantine) and restrictive measures that hinder social gatherings. While each intervention doesn’t provide complete protection, the more interventions there are, the better the protection is.

It may be that as the situation becomes more controlled, there will slowly be a re-introduction into shared indoor spaces, such as offices. How much we limit community spread is what will determine if COVID-19 continues to circulate, like colds and tummy bugs – only more dangerous.

Our next challenge becomes one of logistics, careful planning, and whether equitable access for countries unable to afford the vaccine for their most vulnerable will be championed. But the progress we’ve made in one year since the World Health Organization’s declaration of COVID-19 as a Public Health Emergency of International Concern has been remarkable. Rapid genome sequencing, scientific investigation and multiple vaccine candidates mean elimination is possible. So what state will the world be in a year from now? That’s up to us: as individuals, as government leaders and as a global society. **SF**

by **LOIS KING**
Lois is a PhD candidate in global health governance at the University of Edinburgh.

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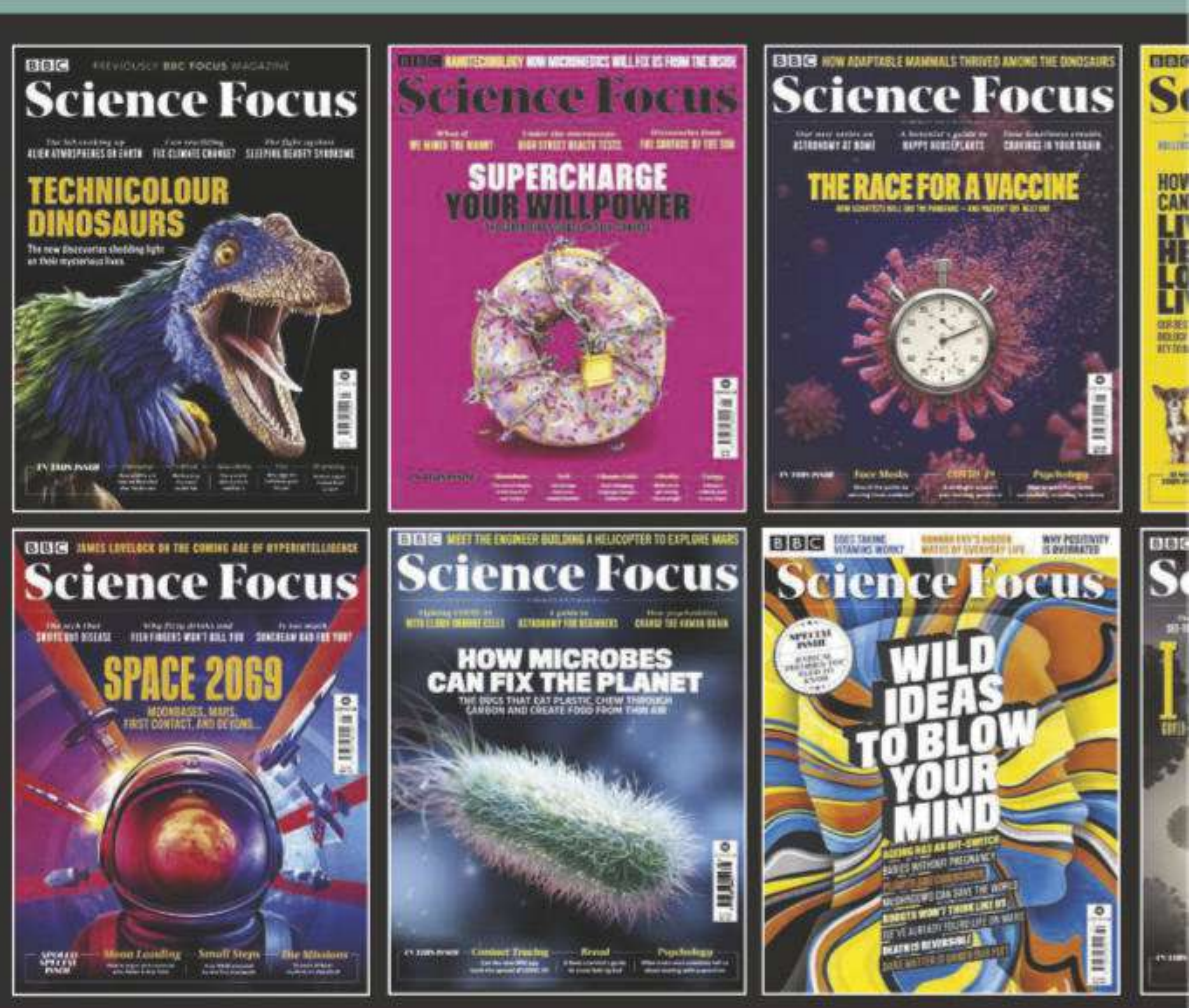

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AN ISSUE*

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

Currently, electric cars take a lot longer to 'fill up' than petrol or diesel cars, which can put people off

LEADING THE CHARGE

SLOW CHARGE

Typically what you get for charging an electric or plug-in hybrid vehicle at home. Depending on the charger and the size of the vehicle's battery, charging up can take between 6 and 12 hours.

FAST & RAPID CHARGE

Fast chargers, often found in shopping centres, come in 7kW or 22kW varieties. A full charge with 7kW unit needs three to five hours; a 22kW unit gets the job done in two. Rapid chargers, found at motorway service stations, need 20 to 60 minutes to fill your battery.

WIRELESS CHARGING

Charging plates in the road top up the battery when the car's stationary. Advances promise to provide charge while vehicles are moving. Trials of the tech are expected to start in Nottingham this spring.

CARS

New fast-charging battery promises a full 'tank' in five minutes

Re-engineered lithium-ion battery lets you fill up electric cars almost as fast as those that run on fossil fuels

Petrol- and diesel-engined cars have forever had one major advantage over electric vehicles: refuelling speed. But that looks set to change with the release of a new fast-charging battery.

In January, Israeli firm StoreDot unveiled its new lithium-ion car battery, which it claims can be fully recharged from empty in just five minutes, a development that could eliminate range anxiety. Said to be the main hurdle stopping more drivers from adopting electric vehicles, range anxiety is the fear of running low on power before reaching your destination, or having to sit around for a long time waiting for the battery to charge.

"IN 2020, BATTERY AND PLUG-IN HYBRID CARS ACCOUNTED FOR 1 IN 10 REGISTRATIONS"

Although most modern electric vehicles can charge in 20 to 60 minutes, they require a special type of rapid-charging station to attain these quick charging speeds. Meanwhile, filling a petrol or diesel car's tank takes between three and five minutes.

The recharge speed of StoreDot's 'extreme-fast-charging' lithium-ion battery technology has previously been demonstrated in mobile phones, drones and electric scooters but the company has now adapted it for use in cars. The batteries differ in construction to conventional lithium-ion batteries in a number of ways, most notably by substituting graphite components for germanium. Germanium has a lower resistance than graphite, allowing faster rates of charge with less heat generation. It also reduces the gradual degradation of a lithium-ion battery – a process known as 'plating' – that fast charging would otherwise accelerate.

StoreDot hopes to make further improvements by switching germanium for silicon, a cheaper alternative, in its second-generation battery, prototypes of which are expected to see the light of day later in 2021.

Faster charging batteries are a welcome development, but they aren't the only barrier to widespread adoption of electric vehicles. Charging infrastructure is also a concern of motorists considering the switch. Despite this, 2020 was the best year ever for sales of electric vehicles, with battery and plug-in hybrid cars accounting for 1 in 10 registrations, according to figures from the Society of Motor Manufacturers and Traders (SMMT). In 2019, that figure was 1 in 30.

It may take longer, however, before we see manufacturers adopt the new technology in their cars. A review published in the *eTransportation* journal, by Anna Tomaszewska and colleagues, suggested that longer, real-world testing would be needed to ensure the new fast-charging batteries could perform well over long timescales.

StoreDot's battery that charges in five minutes

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INTERVIEW

Inside the world's first airport for drones and flying cars

Plans to build the world's first off-grid transport hub for drones and air-taxis have just received government funding. The Urban Air Port, located in Coventry, will offer flying electric vehicles a place to charge and load up. The project aims to lay the groundwork for a web of transport hubs that could provide a green, clean remedy to our cities' groaning infrastructure. Daniel Bennett talks to Ricky Sandhu, the founder and CEO of Urban Air Port, to see if the idea could take off.

WHY DO WE NEED URBAN AIR PORTS?

As an architect and partner at Foster + Partners [an architectural firm], I spent a lot of time developing cutting-edge, innovative buildings and city masterplans, but I never had the scope to tackle the bigger issues involving the bits between the buildings – in other words, our mobility network.

When I first started working on this, my commute was just six miles across London, but it was polluted, congested and took over an hour. So I was just driven by passion and a sense of responsibility that we ought to be developing smarter, cleaner and greener ways to move around our cities.

The urban air-mobility piece came about when Airbus started their air-mobility programme around three years ago. They came to us and said that they knew how to build aircraft, but they didn't understand cities. They were building a new aircraft that would be small, electric and used for short trips – and they wanted to understand what infrastructure could support something like this.

From there, I built a thesis for what this infrastructure could be, and how it would support the different spaces we live in, from super urban cores like Canary Wharf to our countryside. This work led me to realise that this kind of infrastructure will be massive – and hasn't been talked about or invested in enough. And that led to the creation of Urban Air Port Ltd.

WHY NOT LAND-BASED TAXIS AND DELIVERIES?

There's a mass migration happening towards cities and we're all switching to shopping online. There's now a delivery van on the kerb of every street, clogging up our roads. This ultimately exacerbates the problems cities already have. Congestion is getting worse and so is air quality. If we can organise another system whereby there are coordinated locations – like the Amazon Lockers that already exist – that an Urban Air Port will help service with a network of drones, it might go some way to remedying the influx of lorries and vans coming into our cities.

I think this idea for flying cargo could eventually be completely transferable to flying humans. If we can get from A to B quicker, and on zero emissions, then surely that's advantageous.

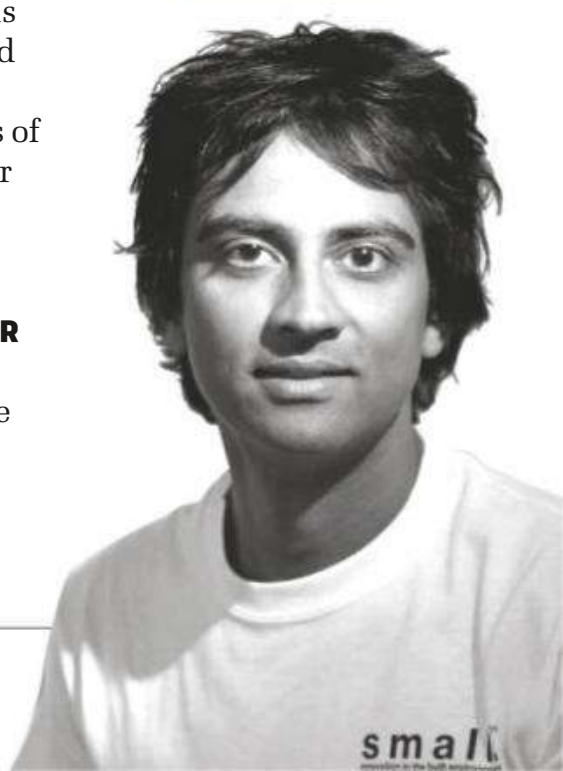
WILL IT BE A TOTALLY GREEN ENTERPRISE?

The first installation in Coventry will be 100 per cent off-grid. It's going to be powered by a hydrogen generator, which is clean. There are no emissions. Of course, there's some carbon intensity involved, depending on the type of hydrogen used and how it's produced. Our aspiration is to get hydrogen from zero-emission sources.

There'll be solar panels too. This isn't just about being clean – it's important that we try and protect our national grid. The adoption of electric cars is going to be an onslaught, so we don't want to add to that. In this first location, there's no access to power. And in future as we grow, there'll be lots of locations around cities that might be suitable for Urban Air Ports where there might not be a big enough supply of energy.

WHY COVENTRY? AND WHY DID YOU PICK THE UK FOR THE PILOT SCHEME?

From a logistics point of view, Coventry is in the centre of England. It's four hours away from all major cities. That's why Amazon has one of its largest fulfilment centres there. There's great



↓ Ricky Sandhu, CEO and founder of Urban Air Port

The Urban Air Ports, as seen in this visualisation, will act as hubs for flying electric vehicles to transport cargo and passengers

proximity to Birmingham and its airport, and indeed the rest of the Midlands.

We're also a British company, I'm from Birmingham and I studied in Nottingham. A lot of my friends went to work in the automotive sectors in Coventry. And that sector is being hit quite hard right now. So there's something quite motivating in the fact that we might be able to create jobs in that area with some talented people.

WHO'S GOING TO BUY THESE URBAN AIR PORTS?

We have a growing pipeline of orders. We're already in receipt of commercial orders from overseas. We've had interest from different city authorities and airports. You can see how this kind of thing can work to ease transit between a city centre and an airport that's 30 to 40 minutes away.

Our partners Hyundai have been able to open doors for us, and they can provide examples of the kinds of vehicles that would use the Urban Air Port.

We're also starting conversations with hospitals and we've had interest from the military in the event of emergency and disaster scenarios. In places where there isn't infrastructure or it's been lost, something like Urban Air Port could immediately be deployed to provide instant connectivity.

HOW MANY REGULATIONS, IN TERMS OF FLYING DRONES NEAR PEOPLE AND CITIES, ARE YOU GOING TO HAVE TO WORK AROUND?

You know, in Ireland there are already drones delivering broccoli to people. And there are deliveries already happening by drone around the world. In Canberra there's even dedicated airspace for cargo drones. In terms of certification, we're working with partners who are building unmanned traffic corridors, highways in the sky. One is currently being designed from Coventry to Kenilworth, a 15km journey. Those are already being drawn up with involvement from the Civil Aviation Authority who are looking to do more trials to understand where these corridors should be and what kind of vehicle should be permitted to travel on them. Ultimately, before we see more air taxis or drones, we're going to need the infrastructure. You can't have trains or planes without train stations and airports.

HOW WILL YOU MITIGATE FOR NOISE?

There are no jet engines or anything like that. In fact, the types of craft being built are competing with one another to be the quietest. That said, a lot of the vehicles using the facility will work like helicopters, so there won't be zero noise.

The important thing is to put that in context, the noise of a city. We've done studies with our engineering partners and with NASA to show that when you have an elevated position for take-off and landing – two storeys, or around six metres above street level – you can barely hear it take off because of the noise created by the urban fabric.

WHAT'S NEXT?

If you look at *The Jetsons* cartoons you'll see there's always infrastructure. There were always these towers where the vehicles and the Jetson family go to. The idea has always been there. And that's what we want to do with this campaign and project: we want to demonstrate that the conversation around mobility has to be around infrastructure. We can't have all have electric cars, for example, if we can't charge them. So let's be ahead of the curve for the next wave of electric mobility and get the infrastructure in place now.

Ideas we like...

→

A see-through speaker...

Apart from public toilets, there are few things in life that aren't made better by being see-through. Case in point, this speaker that replaces its housing with tempered glass. Its creator, a Swedish design studio, says that its speakers use durable, recyclable materials. Each of the devices can be used alone as a Bluetooth speaker, paired together as a stereo sound system, or plugged into existing audio equipment. It's upgradable too, with a compartment at the rear that can hold and power various modules – a voice assistant, for example, or new wireless tech.

Transparent speakers
From £900, transpa.rent

←

A telescope for the social media age

The notion of a telescope without an eyepiece to look through could inspire a few strongly worded letters from our readers, but we can't help but lust after this new telescope from Italian company Vaonis (even if it does cost around £1,300). The Vespera takes the work out of stargazing. The scope grabs the images hitting its sensors and sends a live view to your smartphone or tablet via Wi-Fi. This means you can set up the telescope outside (it has a four-hour battery life), jump under the covers and tour the Universe from the warmth of your bed. The app presents cosmic points of interest to direct the telescope towards, while the motors and GPS aboard the telescope point the lens in the right direction. From there you can watch the view live, or take stacks of photos to share what you're seeing with friends. You can even schedule observations, in case you want to capture something while you're asleep. You'll have to wait until 2022 to get your mitts on it, but its bigger sibling, the Stellina, is out now.

Vaonis Vespera
€1,499 (£1,327 approx), vaonis.com/Vespera

↓

A great-looking smartwatch

Health tech company Withings has been making stylish, fitness-monitoring gadgets for years and their latest watch is no exception. The traditional face hides some of the most advanced tech we've seen in a smartwatch. The medical grade ECG and oximeter take continual readings to measure the health of your heart and respiratory system. It's looking for signals that might suggest you suffer from arrhythmia or apnoea. It's also got activity detection, GPS to log the routes you walk, and can be worn when swimming. Our favourite thing is its battery life, which lasts around 30 days between charges.

Withings ScanWatch
From £208.29, withings.com

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A do-it-all monitor...

This new ultra-HD display from Samsung ticks every box. The M7 is essentially a hybrid between a monitor for a Mac or PC and a smart TV. By day it can connect to your laptop via a single USB-C cable, which will power it too – there's no need to plug it into the wall. By night, it can pull a stream from your smartphone via Wi-Fi or access your streaming service of choice via the built-in Smart Hub software.

The M7 comes with a TV remote and built-in speakers for some reasonable sound (though you might want to add a soundbar to the equation). This means that if you decide to invest in improving your home workspace, then the monitor needn't be shoved into the back of the cupboard when it's safe to go outside again.

Samsung Smart Monitor M7 series
£399, samsung.com

↑

Wireless earbuds with big sound...

Building great earphones is a bit of a dark art. The goal is to create the illusion of a big, spacious sound from something tiny. Most of the time, earbuds can't quite pull off this trick, so you end up with audio that can lack bass, sound tinny or seem distant.

The GT220s from Brooklyn-based, family-run Grado work their magic to avoid all these pitfalls and make the most out of your music. The earbuds handle the big, bassy electronic beats of Run the Jewels just as well as the breathy vocals of Nick Hakim.

We suspect half the reason they sound so good is down to the fit. They easily twist into place and sit there comfortably for hours, without falling out. You get six hours of listening time between charges, and another 30 hours of charge is held in the case. There are plenty of extra features too, like wireless charging, touch controls and a degree of waterproofing.

Grado GT220s
£249.95, grado.co.uk

↓

A wireless charger that charges from across the room...

It's early days, but Xioami has shown off a demo of a product it's planning to put on sale this year. It's called Mi Air Charge technology, and it uses 144 micro-antennae to transfer energy to your phone via a narrow wave beam. According to Xioami's demo, you'd be able to walk into a room and your phone would start charging, even if an object was in the way. Eventually, Xioami says it could be used to charge multiple devices at once in the room it's sat in. It's tech we've seen presented at conferences before, but never so close to an actual final product.

Xiaomi Mi Air Charge
£TBC, mi.com

WASTE NOT, WANT NOT

MEET THE COMMUNITIES FORGING THE WAY TO A TRASH-FREE FUTURE, BY RESHAPING UNWANTED BY-PRODUCTS INTO VALUABLE RESOURCES

WORDS: HAYLEY BENNETT

IMAGES: LUCA LOCATELLI/INSTITUTE

IN BLOOM

The contents of your toilet is precious – to algae, anyway. Human waste is packed with phosphorus and nitrogen, nutrients that algae needs to grow. Researchers have developed bioreactors, like this machinery designed by ClearAS in Missoula, USA, that exploit the way that algae grows rapidly when exposed to human waste. The system is packed with algae that extracts nutrients from wastewater, therefore cleaning the water to ensure it meets industry standards. The algae is then used to make materials for bioplastics and bioenergy.
A full-scale system is up and running at South Davis sewers in Utah, treating 18 million litres of water daily.

↓

SET IN STONE

Geothermal power plants, which use heat from the Earth's core to generate energy, may provide a steady stream of electricity, but they're not entirely clean. They produce some emissions – mostly CO_2 released when hot water is pumped up from carbonate-containing rocks.

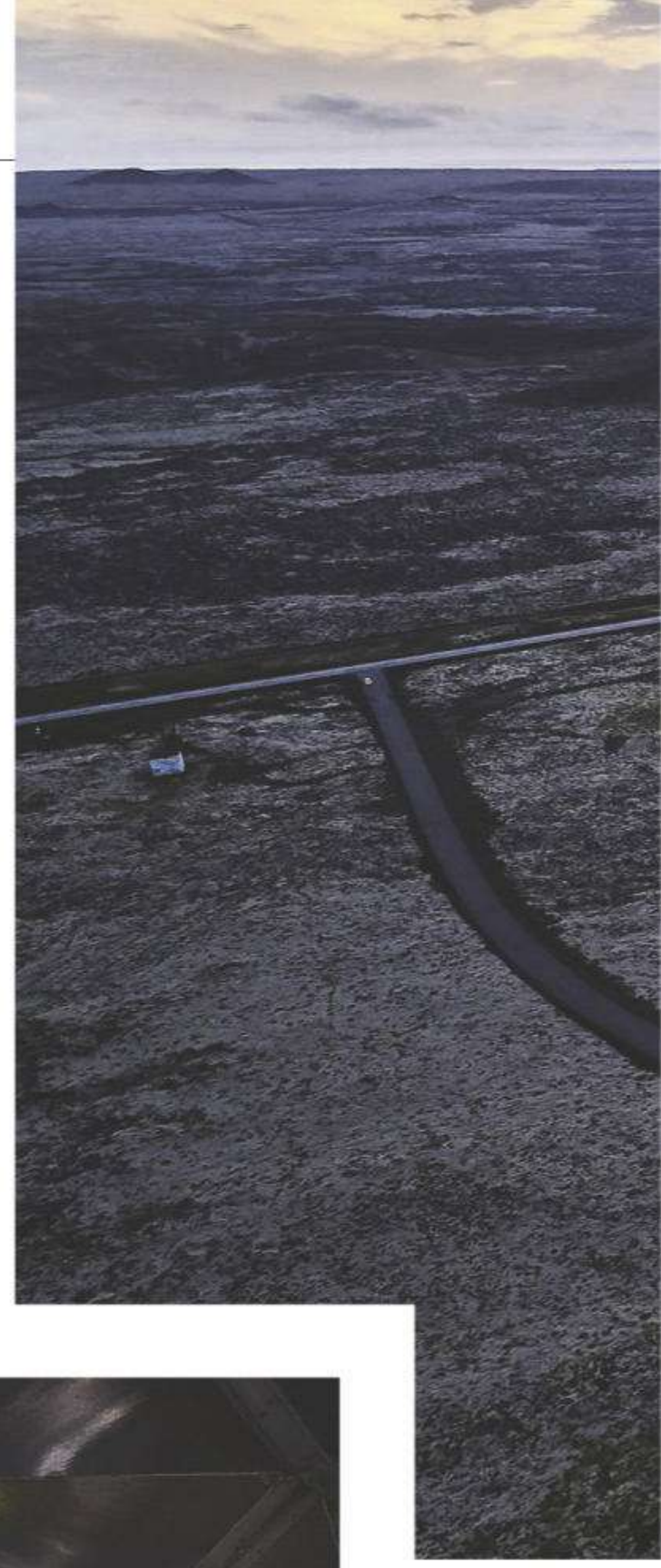
However, at this well (one of over 100 at the Hellisheiði power plant in Iceland) CO_2 can be returned to the rocks by adding it to water that is reinjected back into the ground after energy production. Scientists once thought this 'remineralisation' process took hundreds of years, but a 2016 study showed it is rapid – working within a year or two to lock the CO_2 away. Iceland's CO_2 emissions from geothermal energy are low, but remineralisation keeps the environmental impact to an absolute minimum.

→

GREENHOUSE ON FIRE

Iceland's Svartsengi lava field might seem a bizarre setting for biotech, but beneath the barren landscape in this image is a vast stream of power. As you can see in the background, steam vents from the ground, a visible sign of Svartsengi's volcanic energy.

The region is literally "sitting in boiling water" explains Björn Örvar, chief scientific officer at ORF Genetics, whose 2,000m² carbon-negative greenhouse (front and centre in this image) gets its heat and electricity from the nearby geothermal power station. Inside, 130,000 genetically engineered barley plants thrive year-round in a temperature-controlled, soil-less environment. Rather than using fertilisers that leave harmful by-products, the researchers supplement the crop with minerals from volcanic ash, and bathe the barley in light wavelengths that are specially tailored to plant growth. From the plants, scientists extract human Epidermal Growth Factor and other growth factors destined for stem cell therapies, skin treatments and lab-grown meat.



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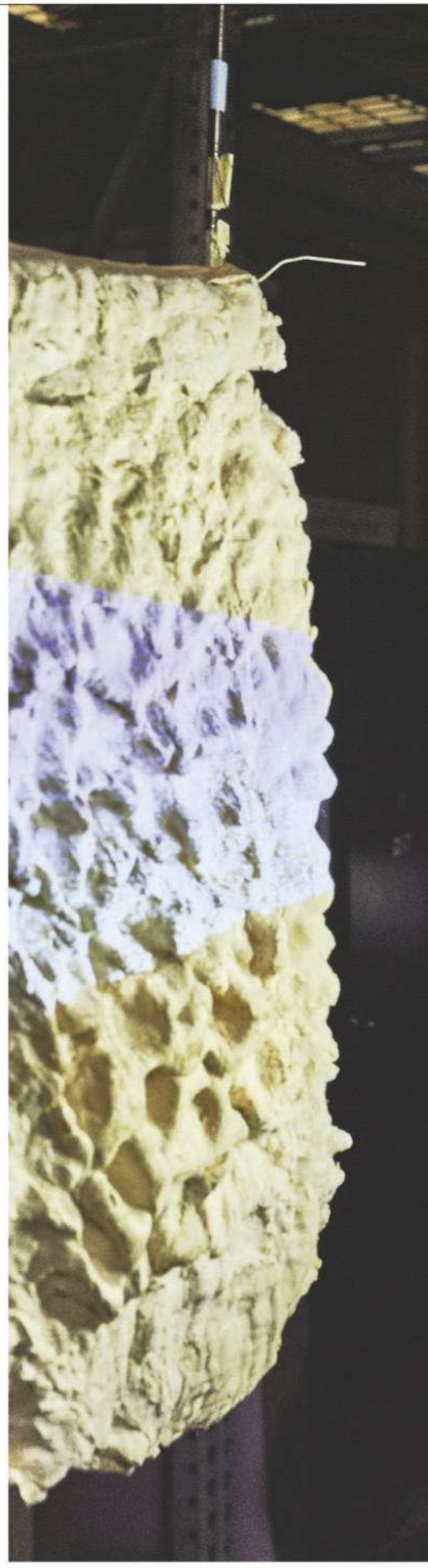
BLOWING OFF STEAM

Due to its large geothermal resources, Iceland makes more energy than it can use. Here, water left over from geothermal power production is allowed to pool in the Blue Lagoon at a soothing 39°C. The lagoon itself is a happy accident. Water used to drive turbines at Svartsengi power plant is brought up as steam (240°C) from deep boreholes. It is so hot that to avoid destroying the turbines it has to be cooled with cold water – cold water that becomes hot waste water. Originally, when this water was released at the surface, workers thought it would seep into the ground, but it didn't. "They threw the hot water here in the lava and slowly, a lagoon started to develop," explains Örvar. Silica gives the water its blue hue, along with species of blue-green algae that live in it.



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DOWN TO EARTH

The starship *Earthship Ark* was the setting for 1970s Canadian sci-fi series *The Starlost*. In the series, the *Earthship Ark* was a spacecraft the size of Sicily on a mission to colonise far-flung planets. In real life there are less fantastical Earthships, but they still aim to be self-sustaining, just like the *Earthship Ark*.

US architect Michael Reynolds is credited with the idea of building affordable homes called 'Earthships', which are made from reclaimed or natural materials. His company, Earthship Biotecture, now offers training in constructing Earthships.

The ideal Earthship collects rainwater, harvests energy from the wind and Sun, stores heat in the walls and floors, and holds space for growing food. Here, workers in Taos, New Mexico, build an insulating wall from old tyres. Other building materials can include mud, dried grass, bottles and cans.

→

MAGIC MUSHROOMS

Scientists are always searching for sustainable replacements for plastic. At Ecovative Design in Green Island, New York, the solution – a gnarly-looking material that grows itself – is not what you might expect.

Lightweight and compostable, Ecovative's patented technology is based on mushrooms. The cream-coloured material pictured here is formed from a fungal network called a mycelium, which grows on farm waste, such as the hulls from cotton seeds. In this picture, a researcher carries out a 3D scan to check its density.

Structures for everything from clothing to car parts can be formed using moulds that shape the growth of the fungi. In the UK, Magical Mushroom Company uses the technology to transform corn husks and hemp into compostable packaging that can be grown to order in just seven days.

←

SLOPE FOR THE BEST

CopenHill, a giant, asymmetric building incorporating a super-efficient waste-to-energy plant, was completed in 2017, looming large over Copenhagen. In 2018, the plant burned 443,000 tonnes of waste, producing 1.25 terawatt hours of energy – enough to keep your phone charged for 463 million years.

The following year, the bosses at the energy plant got a little crazy. "Hey," they thought, "let's build a ski slope on that architecturally impressive roof! And a climbing wall! Why waste the space, huh?"

Almost nothing seems goes to waste at this multifunctional facility. Even the bottom ash from the incineration process is used to make road-building materials. The hope is that by supplying heat and power to nearly 150,000 local homes, the plant should help the city reach its goal of becoming carbon neutral by 2050.

↑

TRASH IS CASH

One company's trash is another's treasure at the Kalundborg Symbiosis park in Denmark, where companies collaborate to save resources. The Novo Nordisk facility pictured here makes half of the world's insulin – used in diabetes treatment – through engineered yeast. Its would-be waste, ethanol and gærfløde (yeast 'cream'), are instead used in biogas and fertiliser production. In this image, an operator checks a pressure gauge while equipment is steam sterilised.

Also at the park is a power plant that was recently converted from coal-fired to biomass-fired: it runs on wood chips, supplying steam for industrial uses and heating for local homes and other on-site businesses.

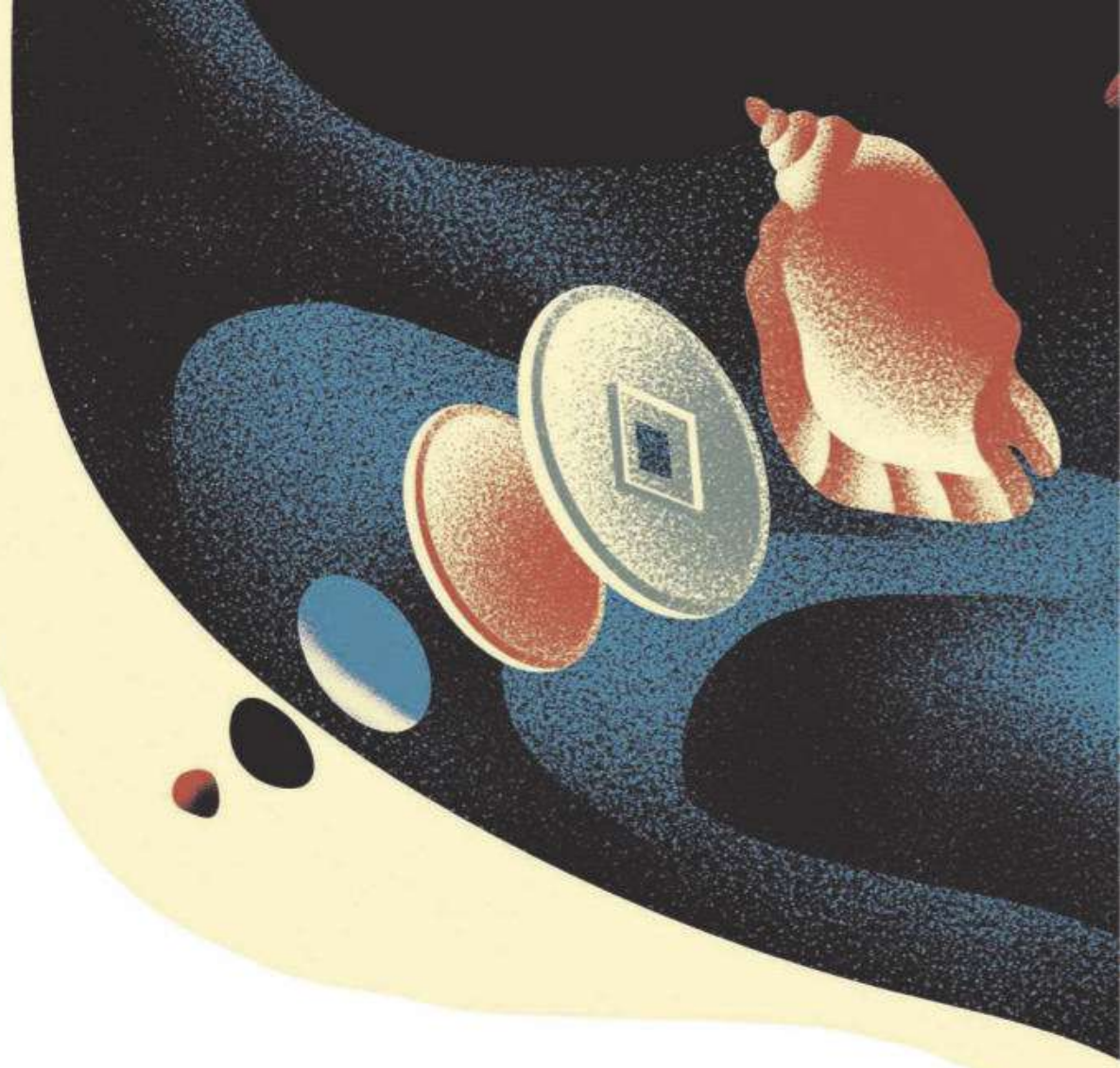
"The main principle is that a residue from one company becomes a resource at another, benefiting both the environment and the economy," explains Michael Hallgren, senior vice president at Novo Nordisk and chairman of Kalundborg Symbiosis. He claims the partnership saves over 635,000kg CO_2 and £21m in business expenses every year. SF

by **HAYLEY BENNETT**
Hayley is a freelance science writer and editor, based in Bristol.

DO WE SEE THE WORLD AS IT REALLY IS, OR ARE WE CREATING OUR OWN REALITY? HERE, WE DELVE INTO THE NEUROSCIENCE BEHIND THE WORLD THAT WE EXPERIENCE

HOW YOUR BRAIN CREATES REALITY

by **LISA FELDMAN BARRETT**
(@LFeldmanBarrett)
Lisa is a professor of psychology at Northeastern University and the author of Seven And A Half Lessons About The Brain *(£14.99, Picador), out 21 March 2021.*



There is a classic Monty Python sketch in which a customer, played by John Cleese, enters a pet shop to buy a cat. The dodgy shopkeeper, played by Michael Palin, whips out a terrier instead and offers to convert the dog surgically into a cat, a budgie, or a fish. "Terriers make lovely fish," he assures the customer. "I could do that for you straight away. Legs off, fins on, stick a little pipe through the back of its neck so it can breathe, bit of gold paint…" In real life, we often view our pets in terms of other animals, and no scalpel is required. Perhaps you've met dogs who are so aloof that they seem like cats, or cats who are so affiliative that they're more like dogs. My family used to have a pet betta fish named Ariel who seemed more puppy than fish. She'd allow us to pet her without complaint, and when we dropped food in the fish tank she'd nuzzle our fingers.

This topic might seem frivolous, but it reveals a superpower of the human brain. We can consider a physical object, such as a fish, and impose new functions on it that are not part of its physical nature, using only our collective minds. To my family, Ariel was a puppy, even though nothing about her body was dog-like. We simply agreed that Ariel had puppyish qualities, and that agreement became our reality. (The perceptive reader may have noticed that I've referred to Ariel as 'she', even though the colourful bettas sold in pet shops are always male. Our daughter, who was three at the time and in love with Walt Disney's *The Little Mermaid*, informed us in no uncertain terms of Ariel's preferred pronoun.)

This superpower to modify physical reality is called 'social reality'. You or I can simply make something up and communicate it to other people, and if they treat it as real, it becomes real. For better or for worse.

Social reality has an astonishing level of influence on our lives. We impose functions on bits of paper and metal and they become money. We draw imaginary lines in the dirt and they become the borders of a country, and the people on opposite sides of those imagined lines transform into citizens with rights, and foreigners without them. Brexit is also social reality. Even your own name is social reality. Someone just made it up, and you and other people treat it as real. In fact, most of us spend most of our time in a real world of serious make-believe.

BRAIN IN A BOX

How do human brains create social reality? To answer this, let's consider it from a brain's point of view. For your whole life, your brain is trapped inside a dark, silent box called your skull. Your brain constantly receives data from your eyes, ears, nose, and other sense organs. It also receives a continuous stream of sense data from inside your body as your lungs expand, your heart beats, your temperature changes, and the rest of your insides carry on their symphony of activity.

All this data presents a mystery to your brain-in-a-box. Together, the data represents the end result of some set of causes that are unknown. When something in the world produces a change in air pressure that you hear as a loud bang, some potential causes could be a door slamming, a gunshot, or a fish tank toppling to the floor. When your stomach unleashes a gurgle, the cause might be hunger, indigestion, nervousness, or love. So, your brain has a problem to solve, which philosophers call a 'reverse inference problem'. Faced with ambiguous data, your brain must somehow guess the causes of that data as it plans what to do next, so it can keep you alive and well.

Fortunately, your brain has another source of information that can help with this task: memory. Your brain can draw on your lifetime of past experiences, some of which were similar to the present moment, to guess the meaning of the sense data. A slammed door, rather than a fish tank, may well be the best candidate for a loud bang if, for example, there is a strong breeze blowing through a nearby window, or if your heartbroken lover has just stormed out of the room and you've experienced similar ➤

ILLUSTRATION: VALENTIN TKACH

exits in past relationships. Your brain's best guess – right or wrong – manifests itself as your action and everything you see, hear, smell, taste and feel in that moment. And this whirlwind of mental construction all happens in the blink of an eye, completely outside of your awareness.

The esteemed neuroscientist Gerald Edelman described daily experience as "the remembered present". You might feel like you simply react to events that happen around you, but in fact, your brain constantly and invisibly guesses what to do next and what you will experience next, based on memories that are similar to the present moment. A key word here is 'similar'. The brain doesn't need an exact match. If you saw Ariel the betta for the first time, your brain could guess that she's a fish because you've seen similar fish before in bowls. Likewise, you have no trouble climbing a new, unfamiliar staircase because you've climbed staircases in the past. So similarity is enough for your brain to help you survive and thrive in the world.

In psychology and philosophy, things that are similar to one another form a category. For example, think about fish, a common-sense category that includes many taxonomic groups of aquatic animals. Fish come in all colours, shapes and sizes. They swim with a variety of motions. Some travel in schools and others are solitary. Some live in oceans, some in ponds, and some in human homes. A typical fish may have fins and scales and breathe underwater, but some fish have no scales (such as sharks), some have no fins (such as the hagfish), and a few can breathe on land (such as the lungfish). Despite this, we still consider all of these creatures similar and call them fish. We would never consider a dog to be a fish (Michael Palin's creation notwithstanding).

"SOCIAL REALITY IS SO POWERFUL THAT IT EVEN INFLUENCES OUR GENETIC EVOLUTION AS A SPECIES"

You might think that categories exist in the outside world, but in fact, your brain makes them. If I ask you to imagine a fish as a pet, your brain creates a category that could include bettas, goldfish and guppies. But if I ask you to imagine a fish in a restaurant, your brain would more likely build a category from cod, haddock and salmon. So a category like 'fish' is not something static in your brain. It is an abstract category that your brain creates, based on context.

The most important similarities forming a category like 'fish' are not about physical looks but about function. You don't eat a betta sandwich for lunch or keep a salmon in an aquarium,

ILLUSTRATION: VALENTIN TKACH

because the function of a pet is different from the function of a meal. Similarly, the function of a fishbowl is usually to hold live fish, but in another context it can become a vase for flowers, a container for pencils or spare change, a drinking bowl for a thirsty dog, a fire extinguisher for a small blaze, or even a weapon to hurl at an attacker.

FEELING FLEXIBLE

Abstract categories are tremendously flexible. Consider the following three objects: a bottle of water, an elephant and a pistol. These objects do not look alike, feel alike, smell alike, or have any other obvious physical similarities. It turns out that they do share a physical function: they can all squirt water. So they form a category. But they also share another function that, unlike water-squirting, is completely untethered from their physical nature. They are members of the category, 'things that would fail to pass through airport security'. This purely abstract category is only based on function and is a product of human minds (other members of this category include cocaine, the Sahara Desert, and loud, rude songs about immigration officials).

Purely abstract categories, in fact, drive many of your actions and experiences. When your brain makes guesses about the sense data around and within you, those guesses often form an abstract category based on function. To explain a feeling of shortness of breath, your brain might construct a category containing physical exercise, a punch in the gut, surprise, lust and a hundred other potential causes that are all similar to the present moment, so it can whittle them down and act. Category construction is the process by which your brain figures out what something is, what to do about it, and how it should regulate your organs, hormones and immune system as it prepares for action.

Abstract categories are also the engine behind social reality. When we impose a function on an object, we categorise that object as something else. Throughout our history, all manner of objects have belonged to the abstract category 'money': not only paper rectangles and metal discs, but also shells, barley, salt, and carved boulders too heavy to move. We even impose the functions of money on intangibles such as mortgages and Bitcoin. We share such categorisations and make them real – sometimes with only a small group, like my family did with Ariel the fish-puppy, and sometimes with a large population, as with money and countries and citizenship.

Social reality is so powerful that it even influences our genetic evolution as a species. Money, for example, is entirely made-up, but it's so real to us that people who have more money live longer. They can eat healthier foods, live more comfortably, and obtain better medical care. These factors influence who is available and healthy enough to reproduce, and how likely it is

"SOCIAL REALITY CAN BECOME COMPLETELY UNTETHERED FROM PHYSICAL REALITY, AS WE ARE SEEING TODAY"

for their offspring to survive and thrive. As another example, various cultures in history have established laws or norms for who may reproduce with whom. Some rules prohibit sex between people of different skin tones, such as the segregation laws in the United States during times of slavery. Others limit childbirth, such as China's former one-child policy which, in a culture that values sons over daughters, led to more male offspring than female and ultimately to millions of Chinese men who cannot marry Chinese women.

Social reality can even shape physical reality. For example, it's a stereotype to think that girls aren't good at maths. When people believe the stereotype, which is social reality, they may expose girls to fewer maths and physics problems than they do boys, creating a self-fulfilling prophecy that perpetuates the stereotype and wastes the potential of half the population.

ILLUSTRATION: VALENTIN TKACH

A more pernicious example is childhood poverty. Research shows that early and long exposure to poverty is harmful to developing brains and may lead to poorer performance in school. Less education increases children's risk of living in poverty when they grow up and have children of their own. Through a vicious cycle, society's stereotypes about poverty, which are social reality, can become the physical reality of brain wiring.

Social reality is normally constrained by physical reality. We could all agree that we can fly through the air by flapping our arms, or that it's healthy to eat glass. But mere agreement won't change the physical nature of things and make these ridiculous ideas true. Nevertheless, social reality can become completely untethered from physical reality, as we are seeing today. Viruses like COVID-19 are physically real. They don't care about human categories; all they require is a nice, wet pair of lungs to occupy.

And yet, in the current pandemic, despite abundant physical evidence, many people still believe and behave like the deadly virus is not a serious problem, leading to further spread.

This potential for untethering leaves social reality fragile and vulnerable to manipulation. Consider democracy, which is social reality on a large scale. The act of voting for a leader, by making and tallying little marks on paper, is meaningful only because we give it meaning and agree on that meaning. Now witness what happened when a US president claimed to have won an election that he verifiably lost by a large margin of little marks. Millions of citizens believed his story anyway, thereby creating an alternative social reality, and a crowd of them broke into a government building in protest, stole and destroyed property, and even caused death. The building in question wasn't just any government building, but one that holds a sacred meaning in a social reality shared by both sides: the US Capitol, home of the United States Congress. The same superpower that gives us achievements like democracy, can also destroy those achievements.

The human brain is one of the most incredible 1.5kg blobs of jiggly meat that evolution ever produced. In every moment, through electricity and swirling chemicals, your brain somehow conjures up the past to predict the future, to control your body and create your experience in the present. An ensemble of human brains together create social reality, a superpower that can turn fish into puppies, boulders into currency, stereotypes into brain wiring, and a person into a president. Any group of people can make up abstract concepts, share them, and weave them into a reality. Consequently, we have more control over reality than we might think, and more responsibility for reality than we might realise or want. **SF**

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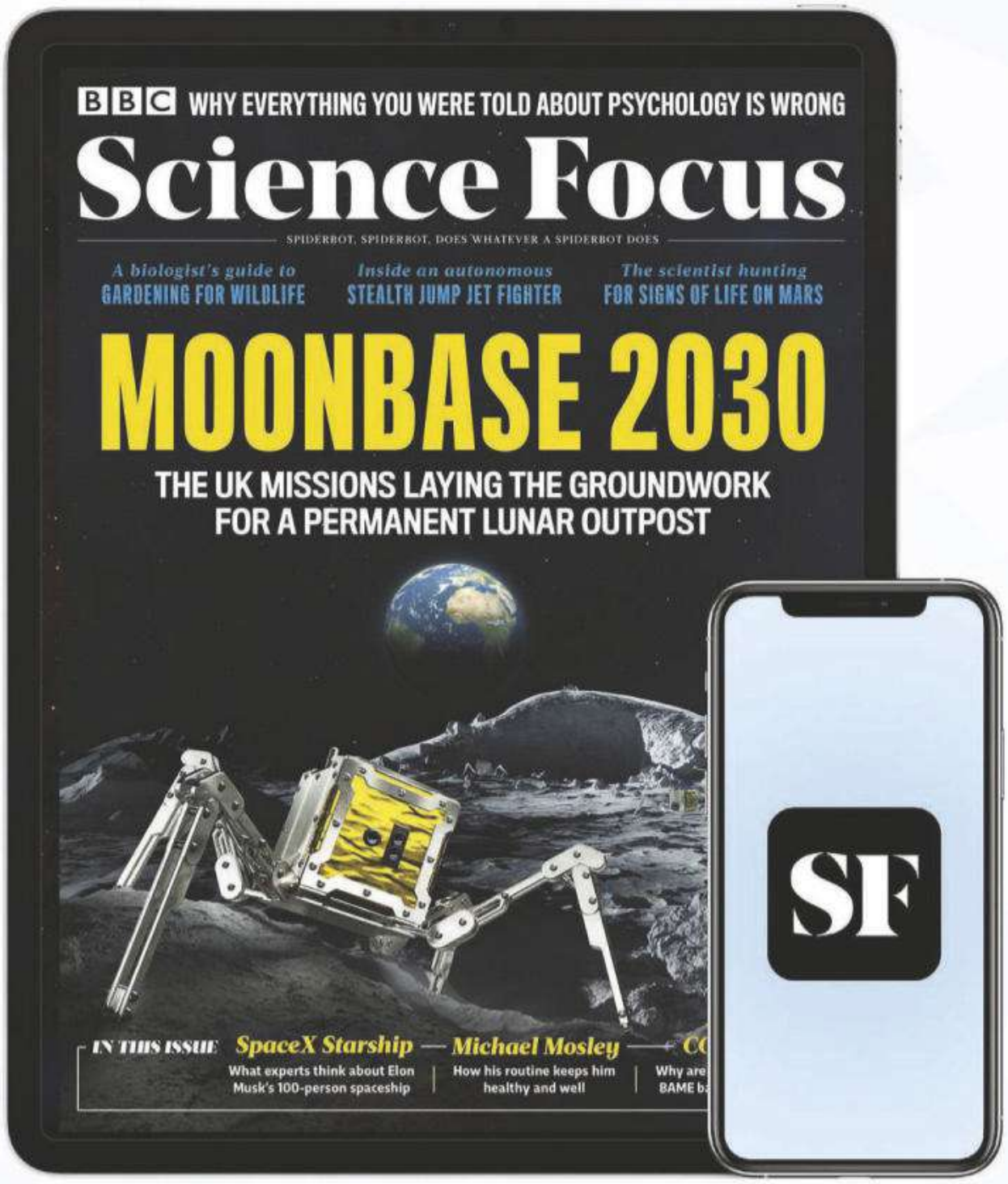
Science Focus

MAGAZINE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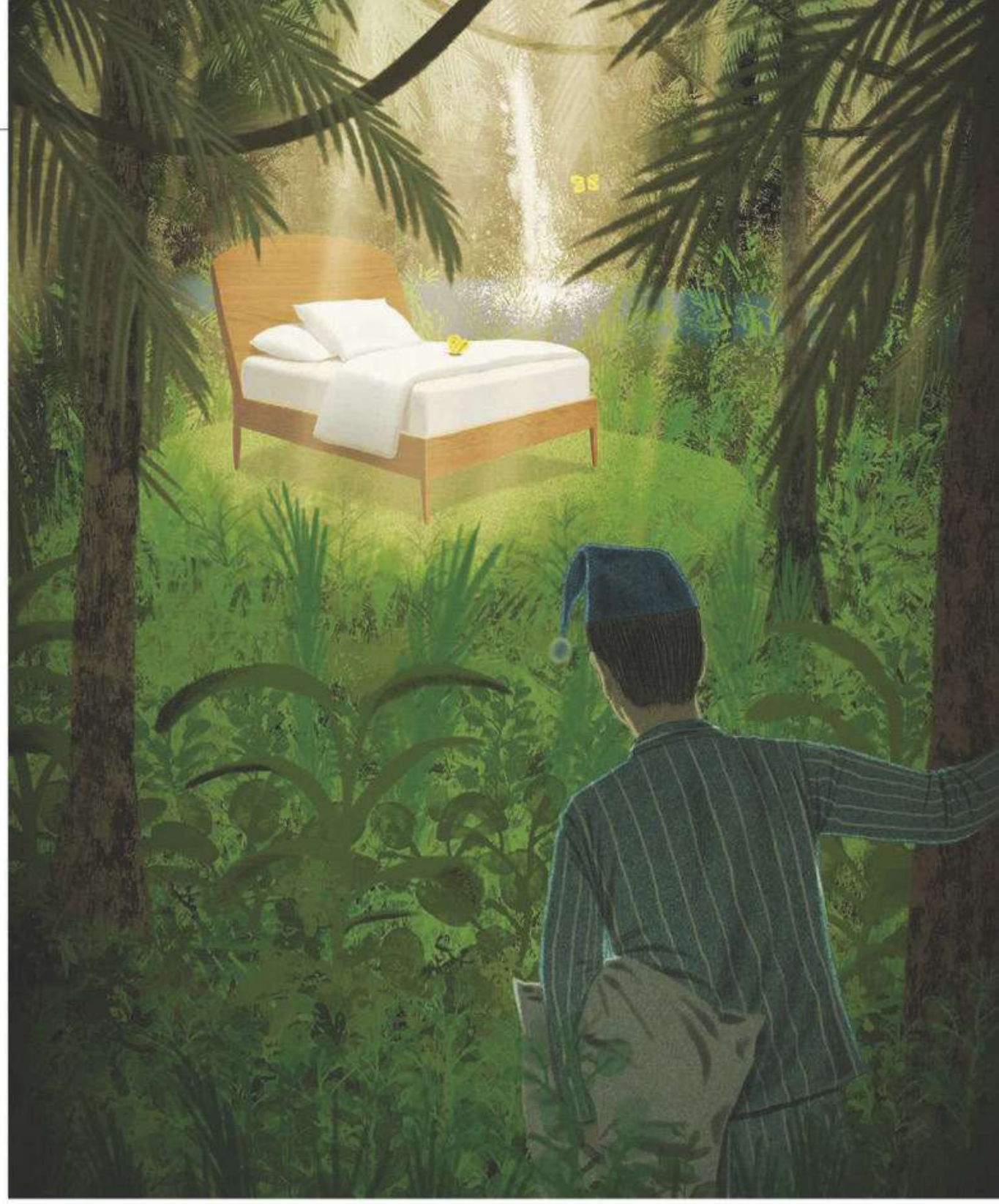
COMMENT

THE QUEST FOR PERFECT SLEEP

Wearable tech and tracking apps can lead to us becoming unhealthily fixated on a good night's rest



Do you suffer from orthosomnia, an unhealthy obsession with getting the right amount of 'healthy' sleep each night? During lockdown, there is evidence of rising rates of insomnia, particularly in health care workers, but orthosomnia is different. It applies to people who are more than a little bit obsessed by what their sleep trackers are telling them, and who rely on those trackers to tell them if they've had a 'good' night's sleep.

The term 'orthosomnia' was first coined by sleep researchers from the Feinberg School of Medicine, Northwestern University, Chicago, who in 2017 wrote a paper called 'Orthosomnia: are some patients taking the quantified self too far?', which was published in the *Journal Of Clinical Sleep Medicine.*

As they explain in their paper's introduction, with more and more people buying sleep trackers, they had started seeing patients whose quest for a better sleep had led to sleep problems. They created the name 'orthosomnia', from 'ortho' meaning correct, and 'somnia' meaning sleep. They also chose this word "because the perfectionist quest to achieve perfect sleep is similar to the unhealthy preoccupation with healthy eating, termed orthorexia".

"Orthosomnia: from 'ortho' meaning correct, and 'somnia' meaning sleep"

One of the case studies they describe in the paper, Ms B, was a 27-year-old woman who had difficulty sleeping because of restless legs syndrome. She was treated and seemed to improve. But a couple of months later she was back, still complaining of poor sleep. So they kept her in the lab. But despite being told that the equipment had shown that she slept deeply, her response was, "Then why does my fitness tracker say I am sleeping poorly?" Although she was offered a course of CBT-I (cognitive behavioural therapy for insomnia), she couldn't afford it and didn't return.

Does orthosomnia matter? The problem is that some people who are obsessed by their sleep trackers then spend extra time in bed, desperately trying to hit their sleep targets. A bit like trying to do 10,000 steps a day. But if you try to do this with sleep, it can be counterproductive. In fact, as I've discovered while researching my books, one of the best ways to combat insomnia is to restrict the amount of time you spend in bed.

I confess that I have a sleep tracker, but I don't obsess over it. The best way of telling if you had a good night's sleep is not the device on your wrist but whether you feel tired or not. SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor.* His latest book is *COVID-19: Everything You Need To Know About Coronavirus And The Race For The Vaccine* (£6.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH

COMMENT

A SAFE SPACE

Intrusive social media and online shouting matches have left people seeking the internet hideouts that allow them to be themselves

My mother is a cool woman, but she is by no means a hacker. And I think her gaming career ended with her (still unbeaten) *Centipede* high score. But for the past year, while isolating during COVID-19, she has been doing an incredibly tech-elite thing: meeting with her friends on their own custom Discord server. Discord – the messaging software that allows voice and video calls, aimed at geeks and gamers – has become the private garden for her social group of mostly retired public health workers. She assures me she is not swapping torrents of *The Great British Bake Off,* or trading in obscure malware. She says they are talking vaccines and mask mandates. But who knows: she won't let me in.

After COVID-19 changed our relationship with digital devices, and politics changed our relationship with mainstream social networks, many of us – regardless of technological sophistication – have opted out of Facebook Groups and round-robin emails. These spaces are too public, and often too limited; my mum's crop of socially distanced 70-somethings need to stream weekly Sunday night dinners, share links, and text chat during movie nights. Their social connection is that they've been friends for decades. They don't need to meet anyone else, but simply be connected to each other. Instead they have found a place they can mark out as private, to gather and cultivate their community on their own terms.

"In their server garden, they are able to be completely themselves. No one is looking, no one is capturing their preferences"

For those of us who've been online since the mid-90s or earlier, this feels like the good old days. 'Social software' was the concept then, not 'social media'. Getting together online was joyful. It wasn't overwhelmed by the feeling of being monetised or being bombarded with someone else's personal advancement. Mum's private Discord garden is of no interest to anyone except the people who are already part of it. And here's the most important thing: in their server garden, they are able to be completely themselves. No one is looking, no one is capturing their keystrokes or their preferences. They can take off their masks (literal and figurative) and relax.

This is vital for our psychological and social wellbeing. More than half a century of research tells us this. If we are unable to let down our guard in a safe space, our mental health suffers. This was why the web of the 1990s was so important to so many. In the time before Facebook, it was the place you could escape to when the offline world was too oppressive. It was where you went to be around the people who wouldn't judge.

The irony is that the last 15 years or so have crowded out those online 'backstages' and sent them offline. Well, without that available to us now, the internet has laid a trail to its secret garden doors, and is inviting us to come inside. For me, it reclaims what I loved about the web. For others, like my mum and her friends, they get to discover something they never knew they didn't have. SF

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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ALEXA, TELL ME A STORY

Dr Lara Martin wants to teach artificial intelligence how to tell a tale and tell it well. She reveals to **Amy Barrett** why we need to train machines how to be storytellers and what *Dungeons & Dragons* has to do with it all....

WHY DO WE WANT TO TEACH MACHINES HOW TO TELL STORIES?

People have been telling stories since before we could write; we're natural storytellers. So if machines were able to tell and understand stories as well, we'd be able to communicate with them more naturally. We're starting to adopt conversational personal assistants – like Alexa or Siri – as a society, but these computers still don't actually know how to converse. The most effective and personal way people have of conversing is by telling stories.

SO TEACHING AN AI TO TELL STORIES COULD IMPROVE OUR LIVES AND TECHNOLOGY?

A lot of people don't realise how much nearly everything we say is a story, or could be framed as a story. I like imagining that you could just talk to your personal assistant, and it would work with you to figure something out. Like maybe you're planning a birthday party for your kid, and you tell it "Hey, I'm planning a party for Gina's 10th birthday. Can you help me?" and it can create a story about this party: "Every good party starts with cake. You could get a cake at the local grocery store, and then while you're there buy some balloons. Once you've set up the decorations..." and so on. The assistant could collaborate with you to come up with this party narrative until you're happy with it. I think there's a lot of cool potential for human-AI collaboration here.

WHERE DO YOU START? AND WHAT ARE THE LAYERS YOU NEED TO BUILD TO TEACH AN AI ABOUT TELLING STORIES?

There are a couple of ways to start. Most modern techniques start with a tonne of stories. You collect or find a bunch of stories, and run them through an algorithm that memorises patterns in the stories, such as fighting the dragon usually comes before saving the princess, for example. Then you – the human – come up with the first sentence of the story and it'll spit out the rest. These systems tend to be really good at generating brand new, grammatical English sentences, but they just ramble on and forget what they were talking about after a little while.

The earlier techniques – which some people are still working on – take a lot more effort to make. These researchers sit down and come up with all of the possible plot points in a story world and how they would connect. The system would then plan out a path to take through these plot points in order to create a story.

DR LARA J MARTIN
Lara is a Computing Innovation Fellow postdoctoral researcher at the University of Pennsylvania, where she teaches AI to generate stories and produce language that is natural and human-like. She earned her PhD at the Georgia Institute of Technology, and a master's degree in language technologies at Carnegie Mellon University. She is passionate about getting young women and girls interested in computer science and technology.

GEORGIA TECH

There isn't as much focus on the language itself because they can just have a sentence or two already ready to display for when the system picks that plot point. They focus on the cause and effect of the plot points in the story: for example, 'Veena needs to get a sword before she can slay the dragon'. Note this is subtly different from the modern methods.

My PhD thesis was about combining various ideas from these two methods. I would take the text generated by the new techniques, and throw it through some rules and constraints, like in the older techniques, to make sure it's actually a possible next sentence for the story.

WHAT KIND OF STORY CAN COMPUTERS TELL?

The older methods create really coherent, detailed stories, but you can only tell stories using the stuff created by hand, which can mean that you can tell really rich stories within a single story world. One of my favourite examples of this is a game called *Façade* created at the University of California, Santa Cruz. You can also think of these types of stories like playing a giant open-world game – like *Skyrim* or *The Witcher* – where all the branches in the story are created or managed by AI instead of a human.

The newer methods create really interesting stories about nearly anything, but they lose coherence really fast because they're so hard to control. A good, popular example of this is *AI Dungeon*, where it starts the story and then you take turns with it like you're playing an old text adventure game.

Both of these examples are interactive story-generation though – they're telling the story with the person instead of by themselves, which differs somewhat from just a computer telling the story, but they give you a good idea of the types of stories AI is capable of telling.

AS A POST-GRAD, YOU WORKED ON AN AI THAT COULD PLAY THE ROLE-PLAYING GAME *DUNGEONS & DRAGONS*, HOW DOES THAT FIT IN?

My work has primarily focused on having just the AI tell more coherent stories. Having an AI actually play *Dungeons & Dragons* is more of an aspirational goal, something I'd like to see the community come together to tackle – and something that I've been chipping away at.

There's just so much that the computer has to be able to do so that it can play the Dungeon Master. [The Dungeon Master in *Dungeons & Dragons* runs the game world for other players and create the story details.] The AI needs to be able to understand what story it's telling, but also understand the parts of the story that the other players are telling. It needs to make sure everyone else understands the story it's telling. It needs to be able to create stories that are intrinsically rewarding, so making a story that the players enjoy. This might include creating interesting characters, instead of focusing on extrinsic rewards like collecting experience points by killing a tonne of goblins.

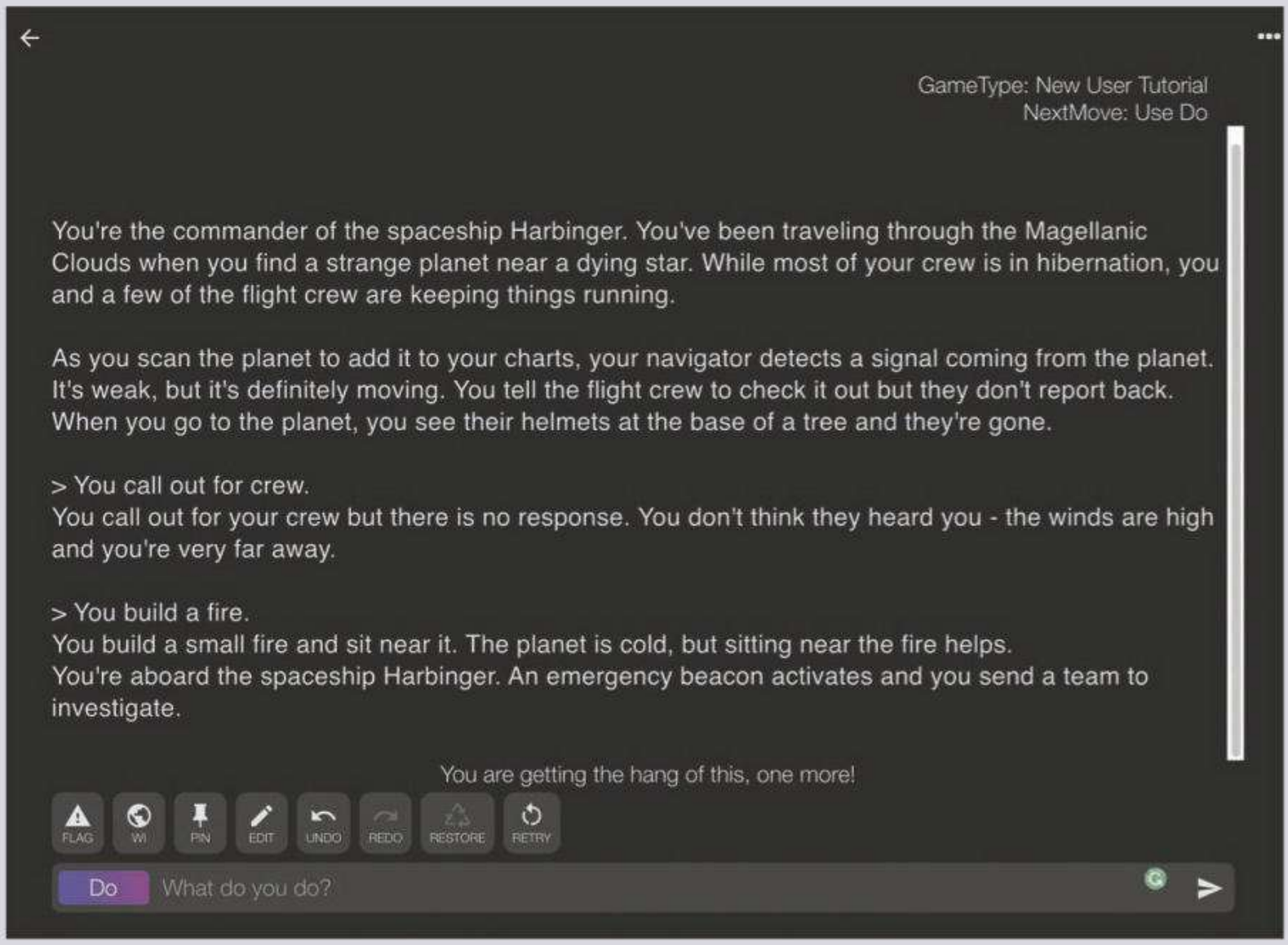
These are just a couple of examples of the hard problems found in playing *Dungeons & Dragons* that aren't solved yet, and it's amazing that humans are able to do it! We can't even make an AI produce a coherent chapter of a book yet. Basically, language is the real monster we need to understand better.

ABOVE In *Dungeons & Dragons*, the Dungeon Master creates the details a storyline, but can react to players' moves. Creating an artificial Dungeon Master would be a true test for computer storytelling

"The computer is not a living thing and I think that it's really important for people to realise that computers are not as smart as they think they are"

WHEN WILL WE GET AN AI DUNGEON MASTER?

To actually see something that acts like a human


GameType: New User Tutorial
NextMove: Use Do
You're the commander of the spaceship Harbinger. You've been traveling through the Magellanic Clouds when you find a strange planet near a dying star. While most of your crew is in hibernation, you and a few of the flight crew are keeping things running.
As you scan the planet to add it to your charts, your navigator detects a signal coming from the planet. It's weak, but it's definitely moving. You tell the flight crew to check it out but they don't report back. When you go to the planet, you see their helmets at the base of a tree and they're gone.
> You call out for crew.
You call out for your crew but there is no response. You don't think they heard you - the winds are high and you're very far away.
> You build a fire.
You build a small fire and sit near it. The planet is cold, but sitting near the fire helps.
You're aboard the spaceship Harbinger. An emergency beacon activates and you send a team to investigate.
You are getting the hang of this, one more!
FLAG
WI
PIN
EDIT
UNDO
REDO
RESTORE
RETRY
Do
What do you do?

Dungeon Master? In our lifetime, I don't know – I'm a little sceptical that it'll happen. We've been making pretty quick progress, but it's extremely difficult.

WILL AN AI EVER BE ABLE TO BE CREATIVE IN COMING UP WITH A STORY, OR IS IT ONLY EVER ABLE TO USE THE IDEAS YOU'VE GIVEN IT?

If an AI agent comes up with something that's new and interesting, and then it brings up questions, well, was that the AI's work or was that the work of the developer or the researcher that created it? There are a lot of legal questions here.

With every AI agent that you make, you're putting your imprint on it, whether you like it or not. The more of the rule-based side you head towards, the more of your imprint ends up in this agent. So, to ask if an AI can come up with something that's creative by itself is a tricky question.

Computational creativity is a really fascinating field because there are just so many philosophical questions that we don't know how to answer. And I'm not a philosopher.

I TAKE IT THAT WE'RE STILL SOME WAY OFF HAVING AN AI WIN THE OSCAR FOR BEST SCREENPLAY?

While I think it would be great to see creative AI being made, having an Oscar-winning AI just has so many problems, as mentioned above. The computer is not a living thing and I think that it's really important for people to realise that computers are not as smart as they think they are. They're not people, they don't have agency. They're just tools that other people have used to work on these things. So I think the best use of creative AI is using it as a tool to augment human creativity.

Computers are extremely good at looking through large amounts of data so they can come up with things that you've never seen before, never thought of as being connected. But humans are really good at taking those connecting ideas that the computer might present to them, and running with it.

I told one of my earliest systems to come up with the next sentence in a story. Most of the time it just came up with random, weird things that didn't work. But then it happened to come with this idea of a horse becoming a lawn chair entrepreneur.

The computer knows nothing about what that means, it's just spitting out stuff. But you could have a human take that and run with it, maybe they go and make a story about this horse – that would be fantastic.

Humans have this ability to connect these things that the AI comes up with, and I think that's a really good, symbiotic relationship that needs to be used more. SF

ABOVE The online adventure game *AI Dungeon*, partly inspired by *Dungeons & Dragons*, uses artificial intelligence to create endless stories and scenarios. Try it at **play.aidungeon.io**

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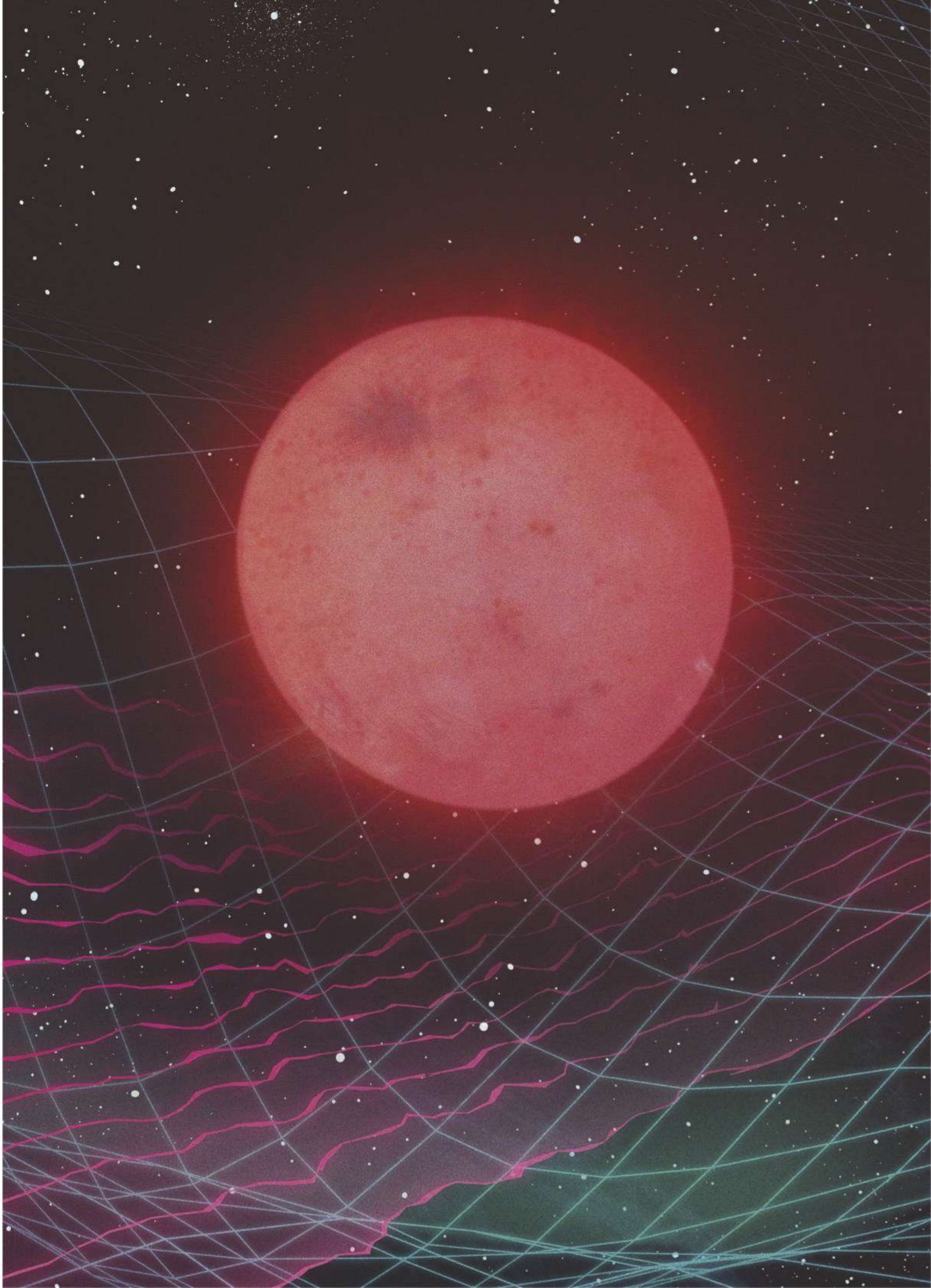


A UNIVERSE FULL OF SEE-THROUGH STARS

Mysterious discoveries around the globe have opened up a tantalising possibility: the cosmos could be full of ghostly stars that are invisible to our most sensitive detectors

by COLIN STUART

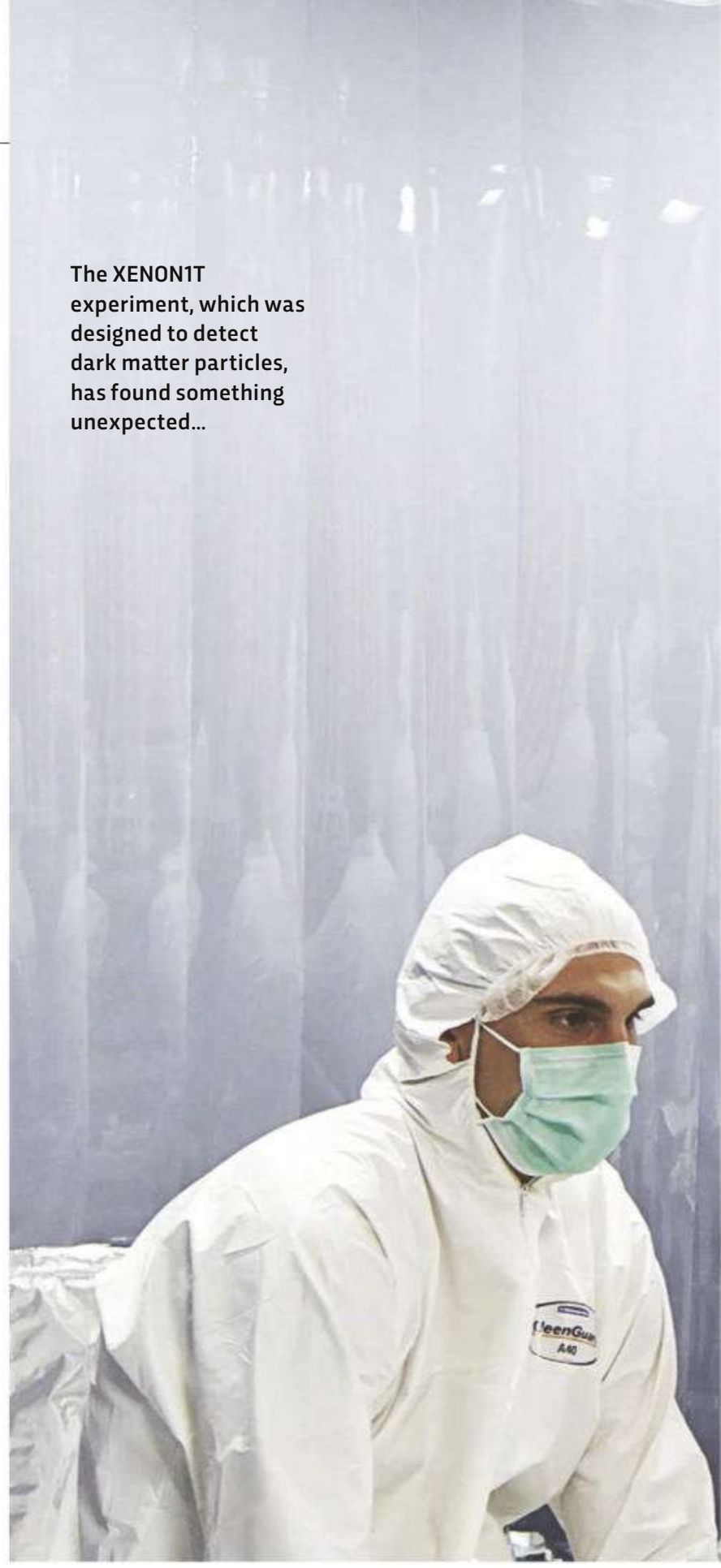
Look up at the sky after sunset and the familiar quilt of night is punctured with bright stars. These blazing furnaces are so vivid that we can see their light, despite the fact that even the nearest are quadrillions of kilometres away. It's a sight most of us have seen on countless occasions, so you'd be forgiven for thinking that all stars must behave this way. After all, isn't shining just what a star does? Yet if a flurry of recent findings is to be believed, there's an entirely different class of stars lurking out there – stellar ghosts cloaked under a veil of darkness. These transparent, invisible stars give out no light whatsoever, meaning they skulk unseen in the celestial shadows.

Astronomers already suspect that, unlike ordinary stars, most of the Universe is hidden from view. When they look at galaxies, such as our own Milky Way, they find stars on the outer edges moving far too fast. So fast, in fact, that they should fly off into space. For them to be kept in tow there has to be something reining them in. The most popular explanation is that there's a lot of hidden material in the Galaxy providing a significant amount of extra gravity. Scientists call this material 'dark matter' and it's thought to outnumber the ordinary matter that you and I are made of by a ratio of more than five to one.

The majority verdict over the last couple of decades has been that this celestial glue is made of Weakly Interacting Massive Particles (WIMPs). This had led physicists on an unprecedentedly intense hunt to snare them. They've built detectors under the ice in Antarctica, in abandoned gold mines and even aboard the International Space Station. So far all their searches have come up empty. It's somewhat ironic, then, that one of our WIMP detectors may have just found evidence in favour of a rival theory of dark matter – one that opens the door to the possibility of invisible stars.

STUDYING THE SMALL

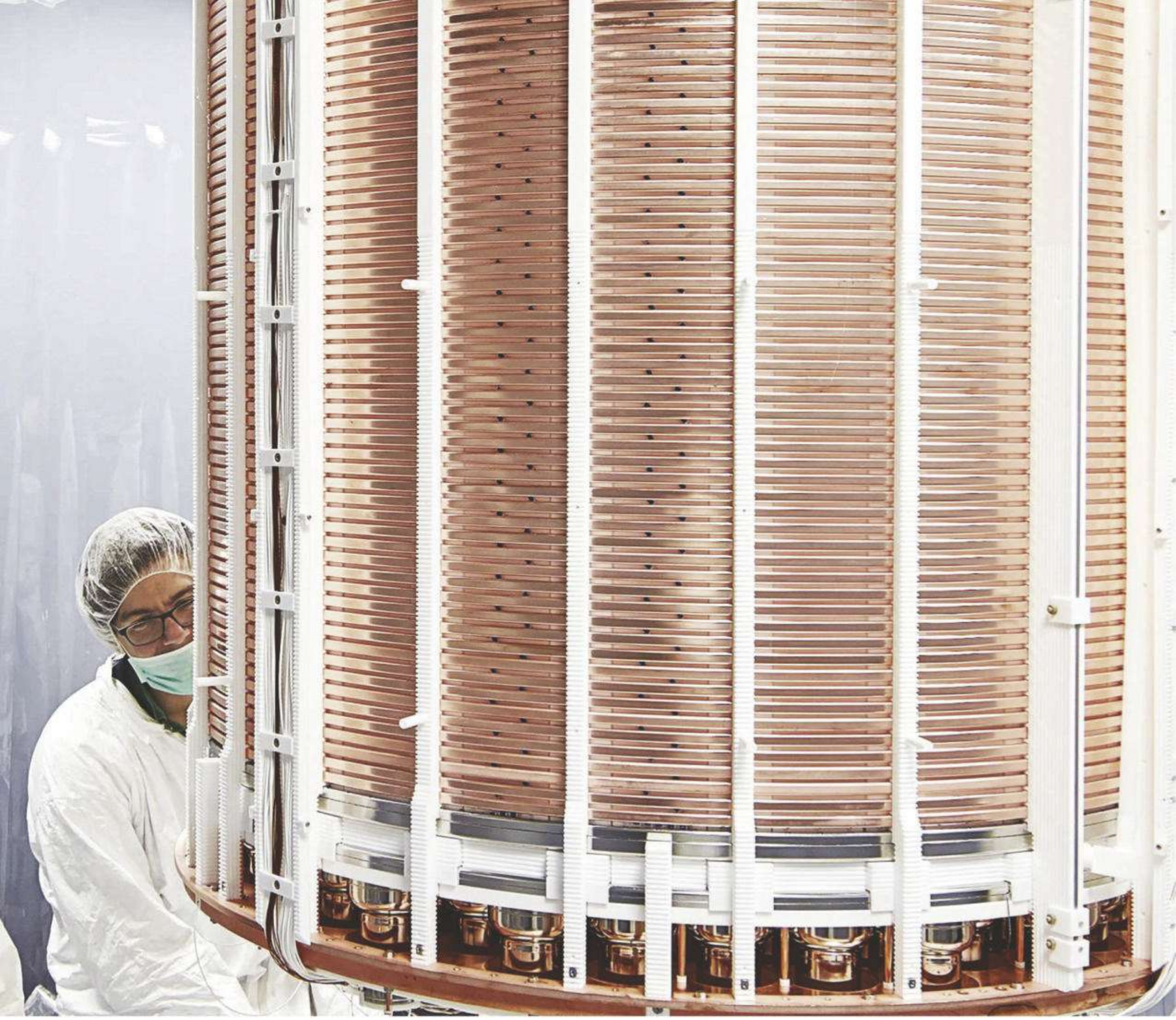
The XENON1T experiment is tucked away 3,600 metres beneath the Gran Sasso mountain in Italy and is the largest underground research facility in the world. A huge tank containing over three tonnes of liquid xenon was designed to act as a WIMP trap – if a WIMP hits an atom in the tank, then the atom will recoil and spit out electrons and photons (particles of light).



The XENON1T experiment, which was designed to detect dark matter particles, has found something unexpected...

ENRICO SACCHETTI

"If dark bosons are affected by gravity, then they should also clump together in the same way that ordinary matter does"



Yet in the summer of 2020, the XENON1T researchers announced that they'd seen something unexpected: an excess of electrons that didn't fit with an influx of WIMPs. According to Dr Tongyan Lin, from the University of California, San Diego, there are three possible explanations. The first two explanations are particles from the Sun, or radioactive contaminants in the experiment. The third, and by far the most interesting, is the arrival of another proposed form of dark matter: dark bosons.

A boson is a subatomic particle that carries a force. The photon, for example, is a boson that carries the electromagnetic force. A dark boson, so the theory goes, could either be dark matter itself or at the very least be responsible for the way dark matter interacts with ordinary matter. If the XENON1T signal stands up to further scrutiny – and the other more mundane explanations can be excluded – it could be the first sign that dark bosons are indeed out there.

A further tantalising hint followed in September 2020, a few months after the XENON1T announcement. Two teams of physicists – one in Europe and the other in the USA – used lasers to confine atoms in a table-top trap. Like all atoms, they contained electrons whizzing around a central nucleus in orbits known as energy levels. Dr Michael Drewsen, from Aarhus University in Denmark, is part of the European team. He says that the presence of a dark boson would create a force that disturbs the atom. "We'd see a small shift in the electron's energy level," he says. While his team didn't find such a shift, his colleagues in the USA did. As always, scientists are a cautious bunch and aren't able to immediately leap to the conclusion that a dark boson really is to blame. "It could be because they were using a heavier atom," Drewsen says. The European team trapped calcium, whereas the American team used ytterbium. Still, their findings, coupled with those from XENON1T, are a shot in the arm for those arguing dark bosons are real. The circumstantial evidence is certainly mounting.

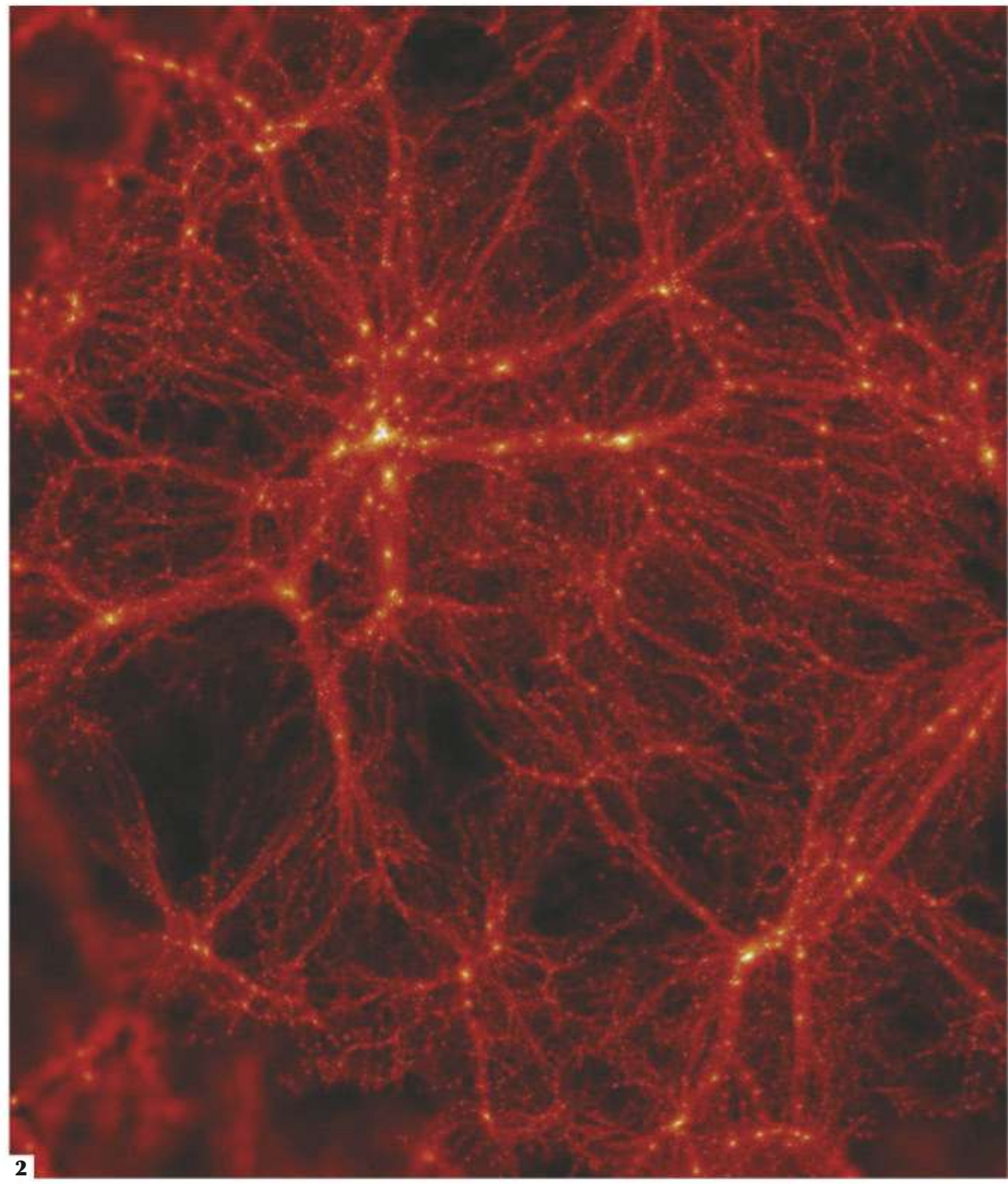
Astronomers are bolstering the case yet further. If dark bosons are affected by gravity, then they should also clump together

in the same way that ordinary matter does. "They would self-gravitate into boson stars," says Hector Olivares, from Radboud University in the Netherlands. These stars would be very different from those strung out in constellations across the night sky. For starters, with no nuclear fusion taking place in their cores, they wouldn't produce any light. They would also be transparent. "Anything that approached them would pass straight through," says Olivares. The lack of any non-gravitational interaction between ordinary matter and dark matter means it would be like a ghost drifting through a wall. After all, the only reason you don't fall through a chair is the repulsive electromagnetic force between the electrons in your bottom and those in the seat.

According to Olivares, a boson star could potentially grow as big as the supermassive black holes (SMBHs) thought to reside at the heart of every major galaxy. In fact, he suspects it may be possible for a giant boson star to initially fool us into thinking it's a SMBH. "Both of them lack a solid surface," he says, referring to the fact that a black hole is a cosmic trapdoor with a point of no return known as the event horizon.

BLACK HOLES AND BOSONS

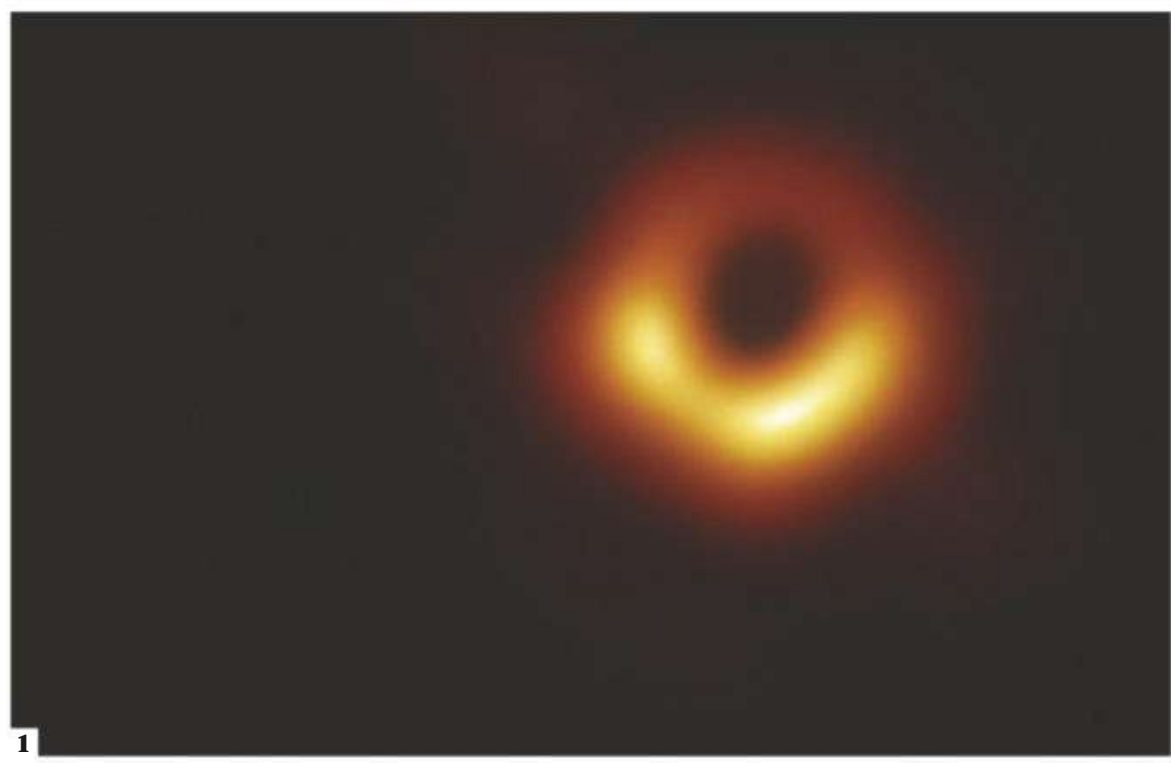
Olivares recently conducted the first simulations of material falling towards a black-hole-like boson star. "We discovered that they are distinguishable from black holes," he says. That's because they lack a shadow. In 2019 astronomers released the first-ever image of a black hole, including a dark region – a shadow – rendered by the missing light that the black hole swallowed. While a boson star doesn't have a shadow – material passes straight through instead of being swallowed – it does sometimes have a feature that does a good job of impersonating one. Olivares calls it a pseudo-shadow. "In most cases we don't see a pseudo-shadow and when we do it's smaller than a black hole's shadow," he says. We could soon use this as a test to see if the SMBH at the centre of the Milky Way is actually a giant boson star. "It's something that can be distinguished using the Event Horizon Telescope [which

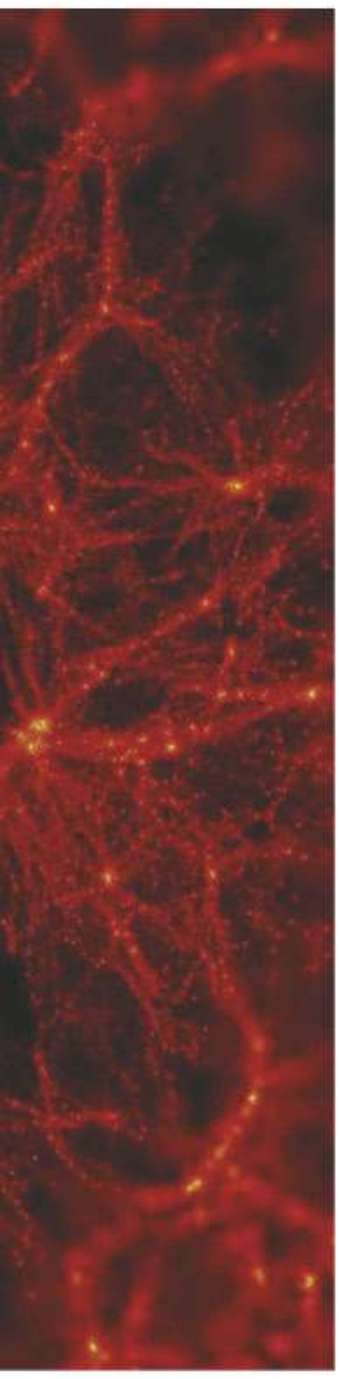


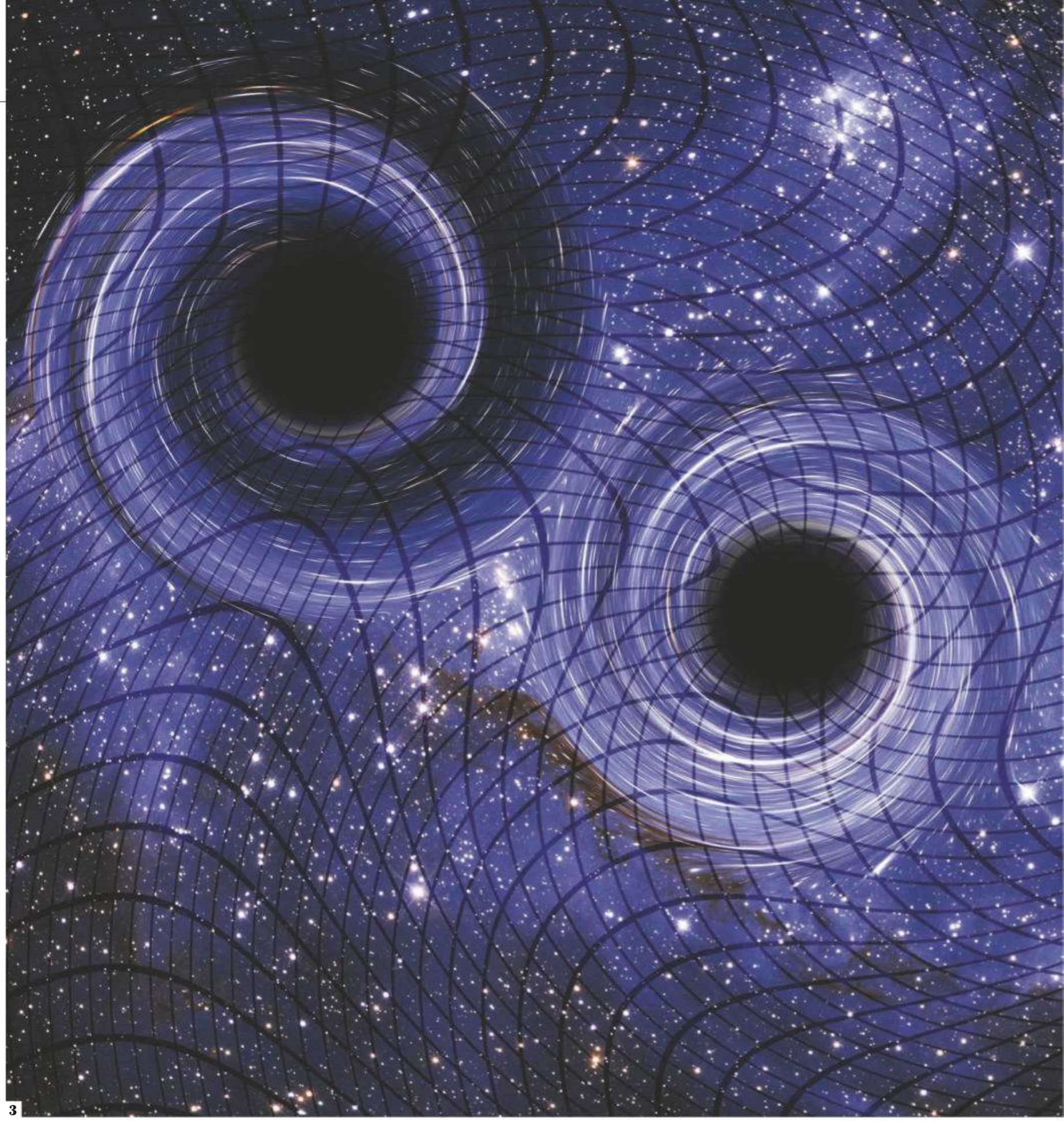
1 The first-ever image of a black hole, seen here, was photographed by the Event Horizon Telescope. The telescope will be used to see if the supermassive black hole at the centre of the Milky Way is actually a boson star

2 Scientists theorise that the Universe is filled with dark matter, as visualised here. The only problem is, we haven't spotted it

3 Enormous celestial events cause gravitational waves to ripple through the cosmos. This could be one way to detect two colliding boson stars







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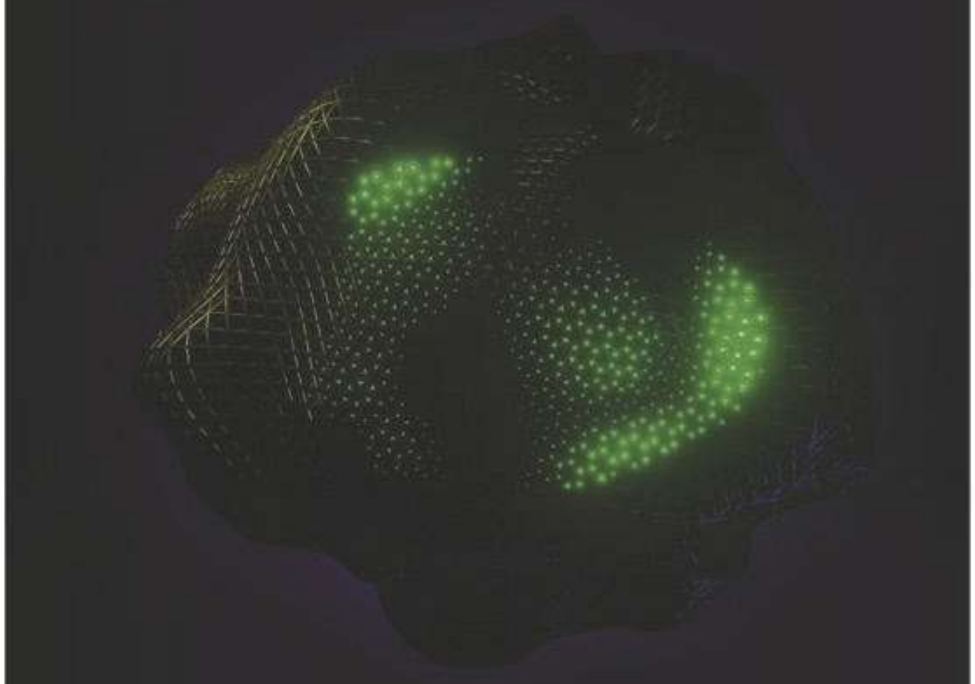
“With no nuclear fusion taking place in their cores, boson stars wouldn’t produce light. They would be transparent”

was the same instrument used to capture the first black hole photograph],” Olivares says. That work is currently ongoing.

While we patiently wait for that result, Dr Juan Calderón Bustillo from the University of Santiago de Compostela in Spain may have already found two boson stars masquerading as black holes. Calamitous celestial collisions create ripples – gravitational waves – which trundle out through the Universe and reach Earth. They were picked up for the first time back in 2015 using the Laser Interferometer Gravitational-Wave Observatory (LIGO) in the USA. The majority of the events we’ve seen so far have been binary black holes – two gravitational monsters orbiting each other before spiralling into oblivion.

Usually, there are three distinct stages to such a collision – the inspiral, the merger and then the new mega black hole it creates. But, according to Bustillo, one particular event sticks out as odd: GW190521. “We don’t see that first inspiral stage,” he says. “It could be a head-on collision instead.” The rest of the black hole mergers we’ve seen so far come from two black holes

WHAT COULD DARK MATTER BE?



PRIMORDIAL BLACK HOLES

Imagine the mass of the Earth crammed into a space the size of your thumbnail. Many cosmologists believe the early Universe spawned reams of these tiny black holes, the combined gravitational pull of which could account for dark matter.

WIMPs (WEAKLY INTERACTING MASSIVE PARTICLES)

Once the most popular candidate, years of empty searches are starting to focus attention elsewhere. WIMPs came from an idea called supersymmetry, in which every currently known particle – such as the electron – has a heavier mirror image.

sub-GeV DARK MATTER

Unlike primordial black holes and WIMPs, these particles would be up to a million times lighter than a proton. A new experiment to try and detect them – SENSEI – is currently being tested at Fermilab in the USA.

AXIONS

The excess of electrons discovered at the XENON1T experiment could point towards these dark matter particles streaming out of the Sun. They were first devised by particle physicists to plug a hole in our understanding of the strong nuclear force.

DARK BOSONS

The lightest of the major dark matter candidates. Evidence is mounting up for their existence from ground-based atomic experiments, along with black hole and gravitational wave astronomy. They could coalesce to form invisible boson stars.

“Boson stars only interact gravitationally with the Universe, so this is the only way they can show themselves”

already orbiting each other. However, if two previously unconnected black holes smashed together, that could explain the lack of an inspiral stage before collision. So Bustillo did the maths, but that explanation didn’t fly. “The gravitational wave signal lasts longer than you would expect,” he says. The resulting black hole also spins faster than it should – a head-on collision wouldn’t provide the same rotational boost as a pair of black holes already pirouetting around one another. “So the gate is open for other explanations,” he adds.

Bustillo wondered if a head-on collision between two boson stars could fit the bill instead. It turns out they can. According to his research, there’s an extra stage in the process for colliding boson stars, compared to colliding black holes. The big boson star created from the two colliding ones oscillates for a bit before becoming a black hole. This extra oscillation stage could explain why the signal lasted longer than you’d expect for two colliding black holes. Bustillo was also able to use the collision data to calculate the mass of the bosons making up the stars. “The value is around the current constraints from other measurements,” he says. In other words, it fits with our existing ideas about dark matter.

The real clincher will come as we see more gravitational waves from collisions without an initial inspiral stage. “I do expect the detectors to see more signals like this,” Bustillo says. If they can also be explained by colliding boson stars, and

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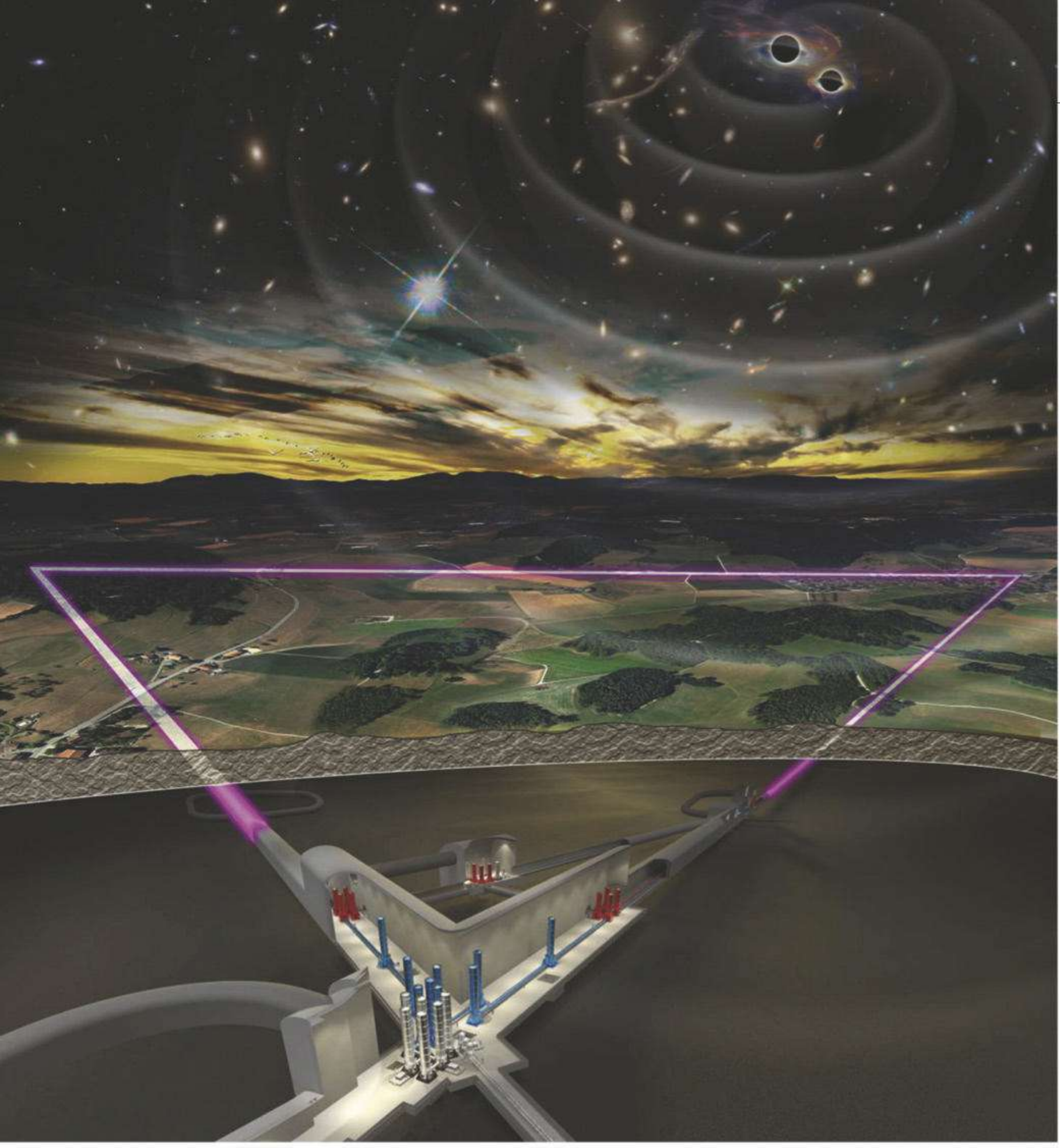

ABOVE
Visualisation of the proposed Einstein Telescope, which will detect gravitational waves and could therefore hunt for boson star interactions

each independent event consistently gives the same mass for the dark bosons, then it'll get harder to ignore the possibility that see-through stars are out there.

Two upcoming experiments could soon join the fray and help us to shore up the case further, according to Dr Costantino Pacilio from Sapienza University of Rome. The first is the Einstein Telescope, a proposed European ground-based gravitational wave detector. The second is the Laser Interferometer Space Antenna (LISA), a trio of spacecraft that will fly in formation separated from each other by 2.5 million kilometres. "They will both have a higher sensitivity than LIGO, meaning we will get a more accurate and detailed look at the shape of the gravitational waves," says Pacilio. That's crucial, because every colliding object imprints its features into the shape of the waves. In particular, the way the two colliding objects deform each other with their gravity provides a unique signature. "Boson stars are exotic objects," Pacilio says. "They only interact gravitationally with the Universe, so this is the only way they can show themselves."

When we invented the telescope, it was to get a better view of the things we could already see. But now, centuries later, it's becoming increasingly apparent that there's a lot more to the Universe than meets the eye. Perhaps it's time to turn our ideas about stars upside-down and accept the fact that there could be just as many invisible stars creeping through the Universe largely unseen. **SF**

—

by **COLIN STUART** *(@skyponderer)*
Colin is an astronomy author and speaker. Get a free e-book at ***colinstuart.net/newsletter***

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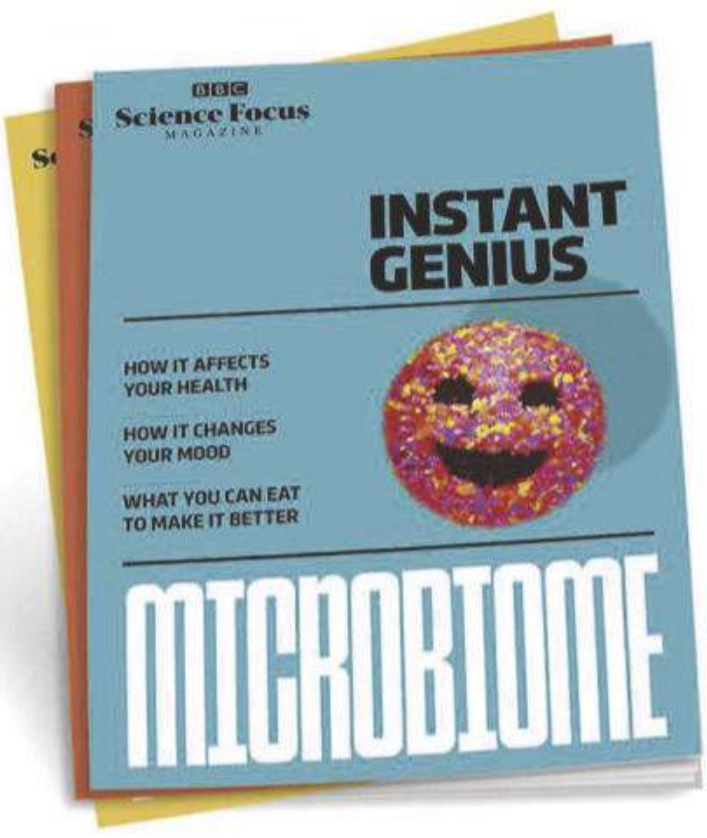

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JOHN AWBERY, READING

COULD WE FARM THUNDERSTORMS FOR POWER?

Sure, it's tempting to imagine harnessing the electrical energy unleashed during a thunderstorm. After all, the average lightning bolt contains an estimated five billion joules. However, capturing and using this energy poses a raft of challenges.

The first conundrum: knowing where lightning will strike. Although lightning occurs roughly 100 times a second around the globe, these flashes are erratic and unpredictable, with only a small proportion reaching the ground.

The next challenge would be to convert the energy into a usable form. Objects struck by lightning can be heated to over 20,000°C, and the potential difference generated is around a hundred million volts. Creating equipment that could safely withstand these extreme conditions would be difficult. Any energy captured would then need to be used immediately or stored, and converting it to the low voltage, alternating current that powers our homes is extremely difficult.

Finally, the amount of energy that you could harvest from lightning may simply not justify the effort. The five billion joules in one lightning bolt amounts to about 1,400kWh – enough to power an average UK home for about four months. In reality, however, a significant proportion of this energy is dissipated into the atmosphere as heat.

All this might explain why the last organisation known to have considered the idea, a US company called Alternate Energy Holdings, gave up in 2007, declaring, "Quite frankly, we just couldn't make it work." ***AFC***

DEAR DOCTOR...

HEALTH ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I EAT SALAD LEAVES TO FEEL HEALTHY – BUT IS THERE REALLY ANY GOODNESS IN THEM?

In short: yes, most definitely! Most salad leaves contain essential nutrients and micronutrients such as vitamins, minerals, water and fibre. Plus, they are low in calories and high in volume – they can fill your plate up without adding too many calories. Remember, 100g of spinach contains half the calories of 100g of apple.

Guidelines recommend eating five portions of fruit or vegetables a day, and salad leaves definitely count. But you need about a cereal bowl of leaves to rack up one portion. And be sure to watch out for salad dressings, which can increase the calorie count significantly (a tablespoon of French dressing alone can add 73 calories – about a third of a bar of chocolate – to your plate).

There are significant differences between leaves, however. At around 96 per cent water, iceberg lettuce is among the least nutritious greens to put in a salad. A helping of kale is a much better: per serving, it contains over double the vitamin C and vitamin K found in broccoli.

Top tip: if you can cook leaves rather than eating them raw, you'll pack more into the same space. If you do opt to cook them, try steaming, sautéing or microwaving rather than boiling to preserve the water-soluble nutrients. ***NM***

DILEEP BAGNALL (LANCASHIRE)

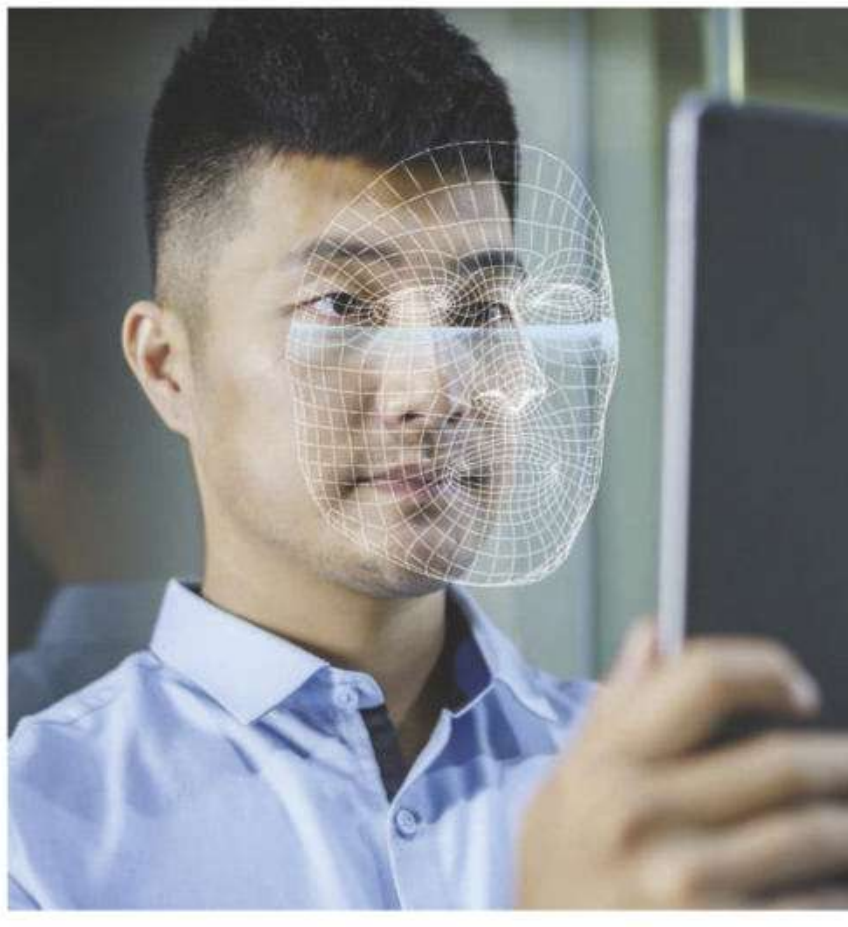
HOW DO WE KNOW THE MILKY WAY IS A SPIRAL GALAXY?

Since we live inside the Milky Way it is difficult to see its spiral form. There are some clues though. First, there is a concentration of stars along the galactic plane and particularly in the constellation of Sagittarius. This implies the Milky Way is disc-shaped with a central bulge, just as we see in other spiral galaxies.

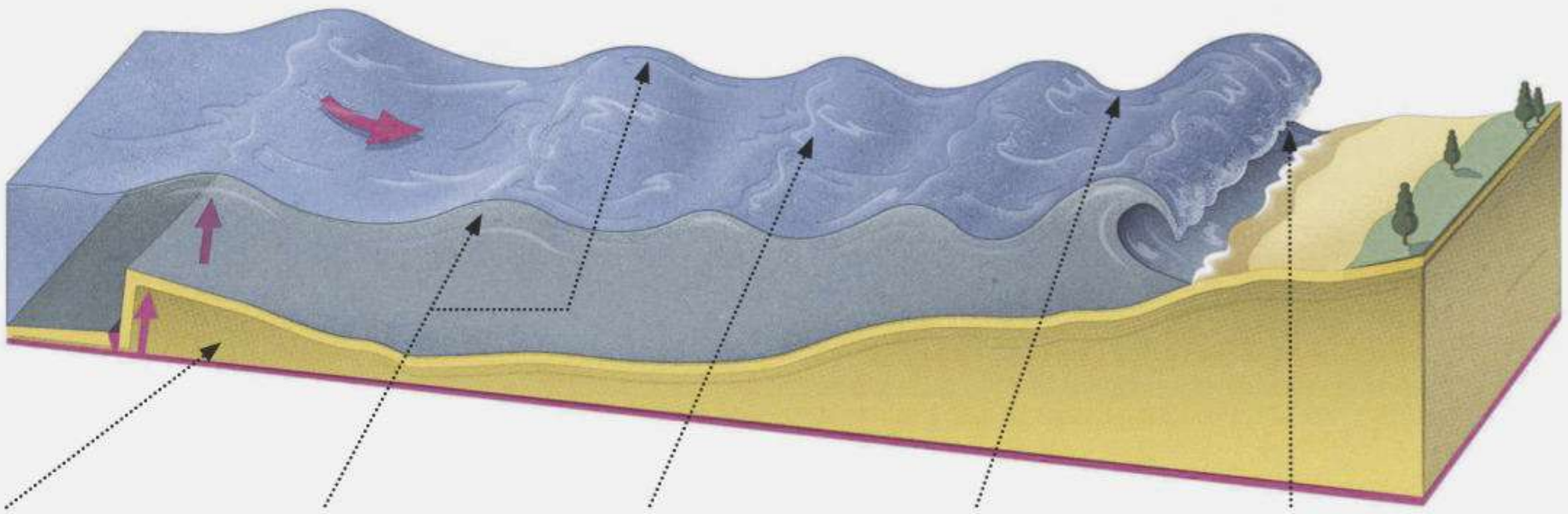
Second, measurements of the velocities of stars and clouds of gas reveal that their motion is not random but follows a rotational pattern – just like those we see in other spiral galaxies

Most convincingly, measurements of the distances of these objects show clearly that they are concentrated along the arms of a spiral. Conclusion: The Milky Way is a barred spiral galaxy with four arms. ***AGu***

GETTY IMAGES X2 ILLUSTRATIONS: DANIEL BRIGHT



HOW DO TSUNAMIS FORM?



1 ACTIVATION
A tsunami begins far offshore, with an earthquake, volcanic eruption or landslide. The sudden movement on the seabed displaces the water above it. Although the vertical movement may initially be less than a metre, it covers a large area and the total volume of water displaced is huge.

2 BUILD
In deep water, the wave spreads out rapidly. The wave may only be 30cm high at this point and hard to spot, but it travels at more than 800km per hour. Unlike normal, wind-driven waves, which are spaced about 100m apart, there can be up to 200km between successive tsunami wave crests.

3 FORMATION
Each wave has a peak and a trough, and sometimes the trough of a tsunami reaches land before the peak. This causes a drawback where the tide seems to go out hundreds of metres further than usual. This drawback lasts for about six minutes before the peak reaches shore, and can catch people out.

4 APPROACH
As the wave crest reaches shallower water, friction with the seabed causes it to slow down. The faster water arriving behind it piles in and pushes the wave crest much higher. The wave height will continue to increase over the next six minutes.

5 IMPACT
Most tsunamis do not have a breaking wave crest, instead they resemble a fast incoming tide. This can push incredible volumes of water up to a kilometre inland, sweeping up people, trees, cars and small buildings in their path. In the next drawback, people and objects can get swept out to sea. ***LV***

EXISTENTIAL FEAR OF THE MONTH

IS AI SEXIST AND RACIST?

We all use facial recognition to unlock our phones. And we all view online content automatically suggested to us. But some of us have rather more success with artificial intelligence (AI) than others.

A study of face recognition AIs discovered that systems from leading companies IBM, Microsoft and Amazon misclassified the faces of Oprah Winfrey, Michelle Obama and Serena Williams, while having no trouble at all with white males. Even the voices of digital assistants such as Cortana or Google Assistant have female voices by default, perhaps unconsciously reinforcing the stereotype of female subservience in the minds of millions of users.

The bias of these AIs is caused by the fact that the current designers of most AIs are largely white males in their 20s and 30s without disabilities. They're generally people who grew up in high socioeconomic areas, often with similar educational backgrounds.

Perhaps unsurprisingly, the resulting AIs are created and educated using narrow and biased datasets that are unrepresentative. For instance, a US government dataset of faces collected for training AIs contained 75 per cent men and 80 per cent lighter-skinned individuals. There's nothing deliberate about this – the AI developers simply didn't notice because they had no experience of diversity themselves.

Thankfully the tide is turning, and today most major tech companies are trying to identify unwanted biases and eradicate them from our technologies. ***PB***

KEITH MAYES, NORFOLK

IS THERE SUCH THING AS A MAXIMUM TEMPERATURE?

Current theories of physics break down once the temperature of an object reaches the 'Planck temperature', which is about 1,000,000,000,000,000,000,000,000,000,000°C.

At that temperature, an object would emit radiation with so much energy that every photon would create its own tiny black hole. The whole Universe was very briefly at this temperature, about 10^{-43}s after the Big Bang. Overall, it's a hundred trillion, trillion times hotter than the Sun. ***LV***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

AM I RELATED TO A VIRUS?

Essentially, a virus is a package of proteins and genetic information that reproduces in the cells of another organism. Viruses are obligate parasites, meaning that they cannot replicate on their own.

Although it's debated whether they're alive or not, they certainly hold genetic information – some of which is similar to ours. But this does not mean that we evolved from viruses.

All life is related to each other to some extent (humans are even somewhat related to mushrooms). However, viruses don't occupy any branch of the tree of life – there is no single common ancestor virus. Instead, viruses share some genetic information with their host.

As a virus replicates in one of your cells, it occasionally copies bits of your genetic information for itself. These related bits of information then evolve within the virus over millions of years and sometimes give it new abilities.

The opposite process also occurs, albeit rarely, where some of a virus's genetic information gets taken by our own cells. This may seem like a bad thing, and can be, but it has also given us new abilities.

For example, bits of a virus that were incorporated into our genomes millions of years ago gave us the ability to make the placenta. Without this virus, pregnancy as we know it would be impossible.

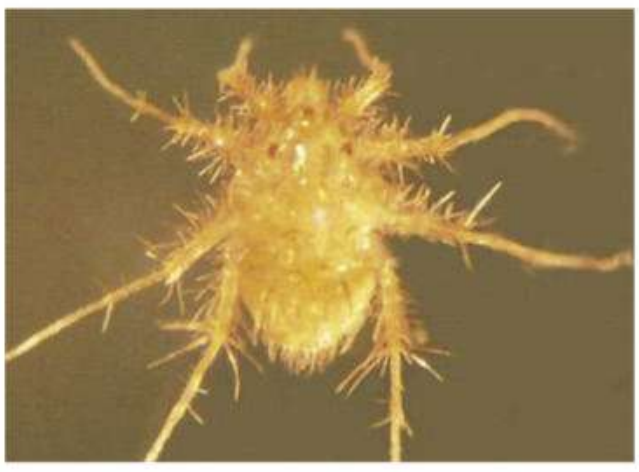
So, no, we are not related to viruses in the standard sense. Instead we have a collection of shared interactions with viruses over millions of years. Many of these interactions cause disease, but some have helped make us what we are today. ***JR***

BEN BASON, SHEFFIELD

WHAT IS THE FASTEST ANIMAL IN RELATION TO BODY SIZE?

And the award goes to.... *Paratarsotomus macropalpis*, a sesame-seed-sized mite that lives amidst the pavements and rocks of southern California. The athletic arachnid has been clocked reaching speeds of 322 body lengths per second, which is the equivalent of a human running at 1,300 miles per hour. It's more than 20,000 times smaller and 40 times faster than Usain Bolt, and it leaves the world's fastest land mammal, the cheetah, eating dust.

If you think that's fast, scientists suspect that the mite's prey could be even speedier, but the elusive animal has yet to be identified or caught on camera. ***HP***



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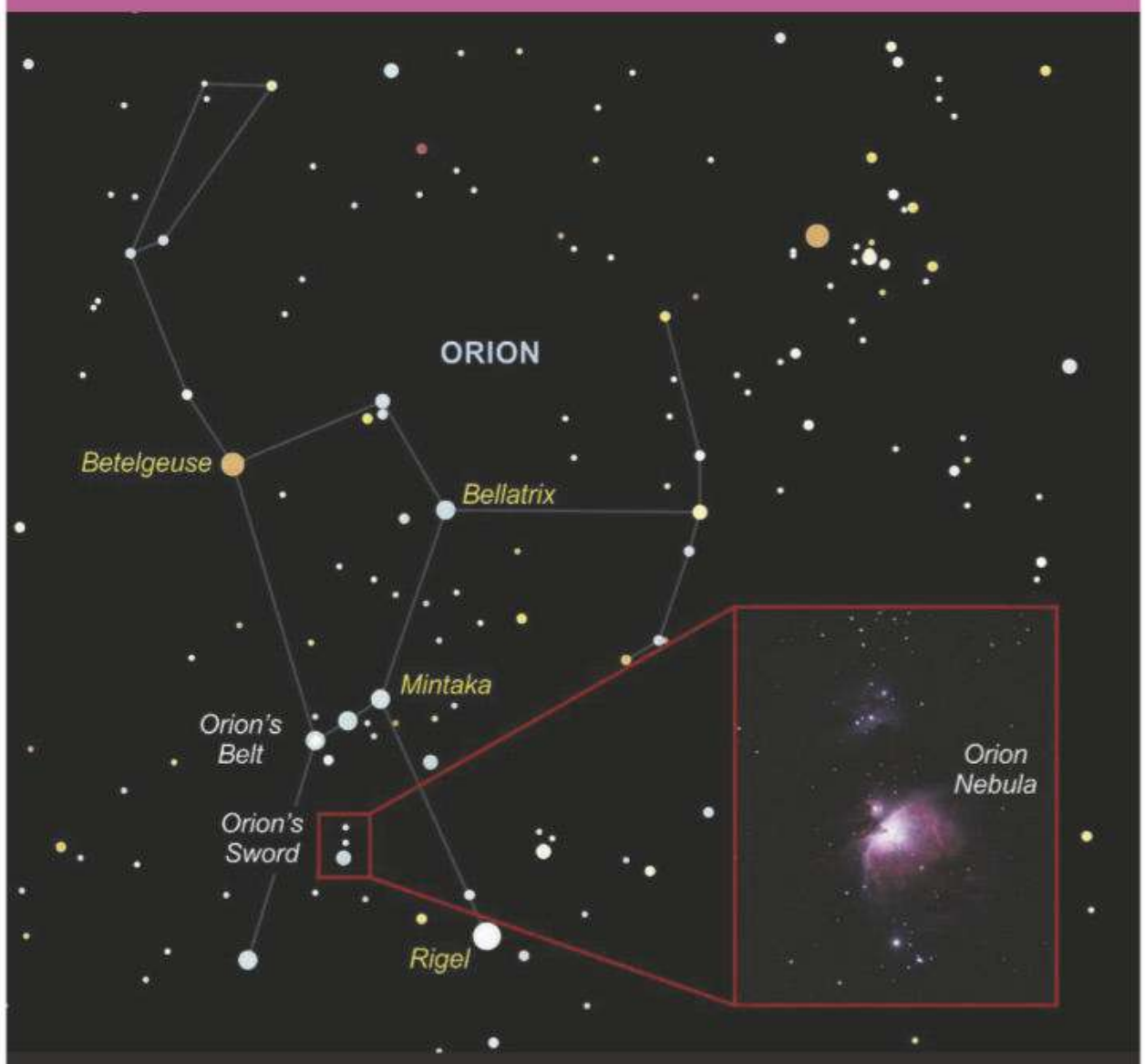
KATE SELBY, DUNDEE

WHY CAN YOU PEE WITHOUT POOING, BUT YOU CAN'T POO WITHOUT PEEING?

The passage of our bodily waste is controlled by circular muscles called sphincters. The external sphincters are under our control. The sphincter around the urethra is smaller than the one around the anus, so when you decide to urinate you can relax it without relaxing the whole pelvic floor. This means you can pass urine without needing to pass stool at the same time.

When you do pass stool however, the relaxation of the stronger anal sphincter also decreases tension in the weaker urinary sphincter, allowing urine to pass at the same time. But this isn't always the case – it is possible, but difficult, to do one without doing the other. ***NM***

ASTRONOMY FOR BEGINNERS



HOW TO SPOT THE ORION NEBULA

WHEN: FEBRUARY TO EARLY MARCH

Nebulae are clouds of dust and gas that represent either end of a star's life cycle. Some are places where stars have died, others where stars are forming. The Orion Nebula is the latter.

At only 1,344 light-years away, the Orion Nebula is the closest and one of the brightest nebulae visible from Earth. This means it can be seen with the naked eye when viewed under dark skies.

The brightness of objects in the night sky as seen from Earth are measured on a logarithmic scale: the lower the number, the brighter the object. This scale means an object with magnitude 1 will be 10 times brighter than a magnitude 2 object. The Sun has a magnitude of -26, while the brightest star in the night sky, Sirius, has a magnitude of -1.46.

The Orion Nebula has a magnitude of 4, which means it is fairly faint – you'll have to go somewhere dark and let your eyes adjust to really see it. It's best to pick a night with no moonlight like the new Moon on 13 March.

Finding the Orion Nebula is easy as it is in the constellation Orion, one of the most easily recognisable constellations. In February and early March, Orion will be visible in the eastern sky as soon as the Sun sets, sweeping south in the northern hemisphere then setting in the west in the early hours of the morning. In the southern hemisphere, Orion will be visible in the north, appearing upside-down compared to how it looks in the northern hemisphere.

To find the nebula, look below the three stars of Orion's Belt (or above, if viewing from the southern hemisphere). You will see a faint line of stars, which make up Orion's sword. The nebula is halfway down the sword and will appear as a fuzzy-looking star. ***AB***

WHAT CONNECTS

CHAINSAWS AND TAEKWONDO

1. A favourite zombie apocalypse weapon, a chainsaw's chain moves at a speed of 27 metres per second. The world's biggest chainsaw, Big Gus, is 6.98 metres long.

2. The chainsaw was first invented to help during difficult childbirths. Really. The device was first designed to cut through flesh and bone if a baby was trapped in the birth canal.

3. While it's untrue that newborns only see in black and white, their colour vision is extremely limited when under two months old. However, they can spot bright red objects when on a green background.

4. Although it's debated whether wearing red can increase performance levels through better visibility or associations with aggression, Taekwondo judges have been shown to award more points to competitors dressed in red protective gear.

FATIMA, MANCHESTER

WHY DO SOME ANIMALS NEED MORE THAN TWO EYES?

Some fish, amphibians and reptiles have a simple third eye on top of the head. This patch of light-sensitive cells doesn't add much to their vision, but it helps some animals to regulate their body temperature and navigate via the Sun's light. Invertebrates often have more than two eyes. Most spiders, for example, have eight eyes that help them spot and hunt prey. A group of marine molluscs called chitons do even better – they have hundreds of eyes dotted all over the armoured plates that cover their bodies. This boosts their field of view and helps them detect predators. ***HP***

ALICE CULKIN, CORNWALL

WHY DOES PORRIDGE GO SO HARD WHEN IT DRIES?

Simple: oats are up to 60 per cent starch, which is a thickening agent. Starch is a carbohydrate that forms granules made from polymers called amylose and amylopectin. When you cook oats in water or milk, the starch granules swell to absorb liquid and the porridge starts to thicken.

When porridge cools, the amylose and amylopectin polymers become less energetic. This means they interact with each other to expel water and form a stronger scaffold. And, as the freed water evaporates, the porridge hardens. ***ED***

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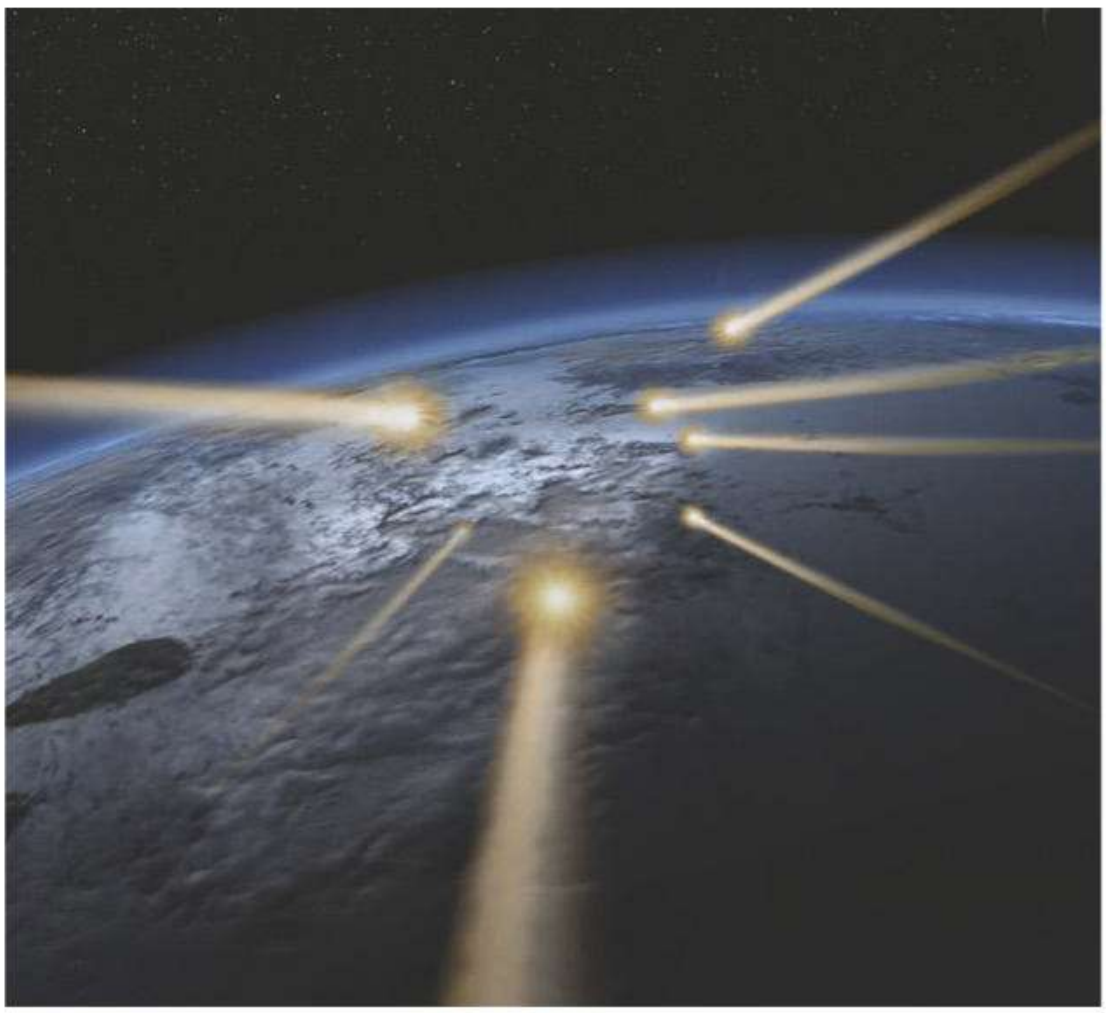

AARON HACON

IS THE TOTAL MASS OF THE EARTH CHANGING?

Scientists estimate that the Earth gains about 40,000 tonnes of material each year from the accretion of meteoric dust and debris from space. They also estimate that about 95,000 tonnes of hydrogen gas are lost from the Earth's atmosphere to outer space each year. Although there are other processes involved, such as the loss of mass due to radioactive decay within the Earth's core (about 160 tonnes a year), and helium loss from the atmosphere (about 1,600 tonnes a year), these are small effects. Annually, the amount of mass launched into Earth orbit is negligible by comparison, of the order of a few hundred tonnes.

A conservative estimate therefore implies the Earth is losing something like 50,000 tonnes of mass every year. That sounds like a lot. But, since the Earth's mass is about 5.97 billion trillion tonnes, it would take about 120,000 trillion years for it to completely disappear at this rate of depletion. That's many millions of times the age of the Earth. In fact, it's many millions of times the age of the Universe! So, this loss of mass has no effect on planet Earth – or on humans. ***AGu***

QUESTION OF THE MONTH

CHARLOTTE HEWES, AYLESBURY

WHY DOES THE PASSING OF TIME CHANGE WHEN WE DREAM?

As many of us know, dreams can feel like they span several days or occur in slow-motion. And they can also be perceived to take place in real-time. Although difficult to analyse time-perception in people's dreams, promising research has emerged when studying lucid dreamers. These are people who are aware they are dreaming *while* dreaming – and can consciously influence the dream content.

For instance, in a study by scientists based in Switzerland and Germany, the time taken to perform pre-arranged tasks when awake and when dreaming lucidly was compared. The participants moved their eyes left-right-left-right to indicate the start and end of a task.

Motor tasks, such as performing squats, took significantly longer when dreaming as compared to when awake (although non-significant differences were found for a non-motor counting task). The authors hypothesised that this could be due to a lack of feedback from muscles when a motor task takes place while dreaming. A difference in neural processing speed when dreaming as compared to when awake was also given as a possible explanation.

Some people wonder why their dreams appear to take place just prior to waking. One possible explanation is that we need to wake up to remember our dreams, which means that those taking place earlier in the night are less likely to be recalled. Dreams are most likely to occur during Rapid Eye Movement sleep, which is more abundant as the night progresses and towards our waking time, providing a further explanation. ***AGr***

WINNER

Charlotte wins a **EZVIZ Full HD Indoor Smart Home Security Camera,** worth £59.99. The camera includes a magnetic base, making it easy to position in multiple locations in the home, and you can view footage via the app. It's a great first purchase for anyone interested in upping their security. **ezvizlife.com**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

THE EXPLAINER

HOW DOES MEMORY WORK?

WHAT ACTUALLY IS MEMORY?

Memory, in short, is a process. It begins with an 'encoding phase' when experiences are represented in webs of interconnected neurons.

Over the short term – imagine briefly memorising a phone number – this takes place at the front of the brain. If you process information deeply enough it will work its way through into longer-term storage, which involves the hippocampus in the brain's medial temporal lobe (near the ears).

Psychologists distinguish between memory for knowledge, which they call 'semantic memory', and memory documenting past experiences, known as 'autobiographical memory'. These two kinds depend on somewhat different neural systems, meaning it's possible for illness or injury to interfere with one while leaving the other relatively intact.

Another distinction is between 'explicit memory' – memories you can recall at will – and 'implicit memory', which is when the information is in your brain, but you can't consciously access it.

WHY DON'T WE REMEMBER EVERYTHING?

A key reason that we don't remember everything is that we don't encode it in the first place. There's also a bottleneck in short-term memory: research has shown it generally has a limit of just seven 'items' (think digits or objects), plus or minus two. Plus, the majority of information in short-term memory isn't passed into long-term memory. In other words, our limits for remembering happen early in the process, rather than due to lack of storage space. Indeed, long-term memory capacity is vast. In an MIT study, people spent five and a half hours looking at almost 3,000 pictures. In a memory test later that day based on these images, they achieved about 90 per cent accuracy.

A minority of people with 'highly superior autobiographical memory' can remember each day of their lives in exquisite detail. The fact most of us can't is probably down to the disadvantages this can bring – imagine remembering every embarrassing or upsetting experience you ever had.

ARE PHOTOGRAPHIC MEMORIES REAL?

There's a basic misconception about memory that it's akin to a video recording. It's not: memory is more of an active reconstruction of what happened. From this mistaken metaphor, people have the idea that some other individuals can glance at something and then recall every detail with perfect accuracy. It's true those known as 'super memorisers' are capable of astonishing feats of memory, but this is mainly through mnemonic techniques (mental strategies that aid encoding and recall) and staggering levels of practice. Using such methods, the current world record holder for memorising the number pi, Rajveer Meena, managed to recall 70,000 digits in the right order.

There is a concept related to photographic memory known as 'eidetic memory', which describes some people's experience of 'seeing' remembered material as if looking out at a photo or visual scene. However, when researchers have tested self-identified eidetic memorisers, they've performed no better than control participants, further challenging the mythical notion of photographic memory.

HOW CAN WE IMPROVE OUR MEMORY?

To improve your memory, focus on boosting the initial encoding process and consolidating the information to ensure it passes into long-term memory. This is the strategy used by memory athletes. For instance, you can overcome the bottleneck of short-term memory by splitting information into chunks (acronyms are handy for this). Plus, the more emotionally striking the material, the more deeply it will be encoded. This is why super memorisers will often convert material into amusing or ridiculous images. Next, repeatedly testing yourself will help to further transition material from short-term to long-term memory. That's because each act of recall reconstructs the memory and encodes it more deeply. Another trick is to exploit our knack for remembering spatial layouts by placing to-be-remembered material along a highly familiar route, such as the rooms of your house or the journey to work. This is the popular and ancient 'method of loci' or 'memory palace' technique. Unfortunately, none of this will help you remember where you left your car keys if you weren't paying attention when you put them down! You need to effectively code this information in the first place.

WHY DO WE LOSE MEMORIES AFTER HEAVY DRINKING?

From lab research with rodents, scientists have established that the phenomenon likely occurs because of the way that alcohol can interfere with functioning in the hippocampus, thus preventing short-term memories from being passed into long-term memory. There is a 'dose-response' effect: lower alcohol levels can impair hippocampal function, whereas higher levels can block it entirely – hence leaving you with either a fragmented memory or a total 'blackout', respectively. To avoid blackouts, try to refrain from drinking too much too quickly, thus preventing the alcohol levels in your blood from peaking too high.

by DR CHRISTIAN JARRETT

Christian has a PhD in cognitive neuroscience, and is an associate fellow of the British Psychological Society. He is author of Great Myths Of The Brain *(£15.99, Wiley).*

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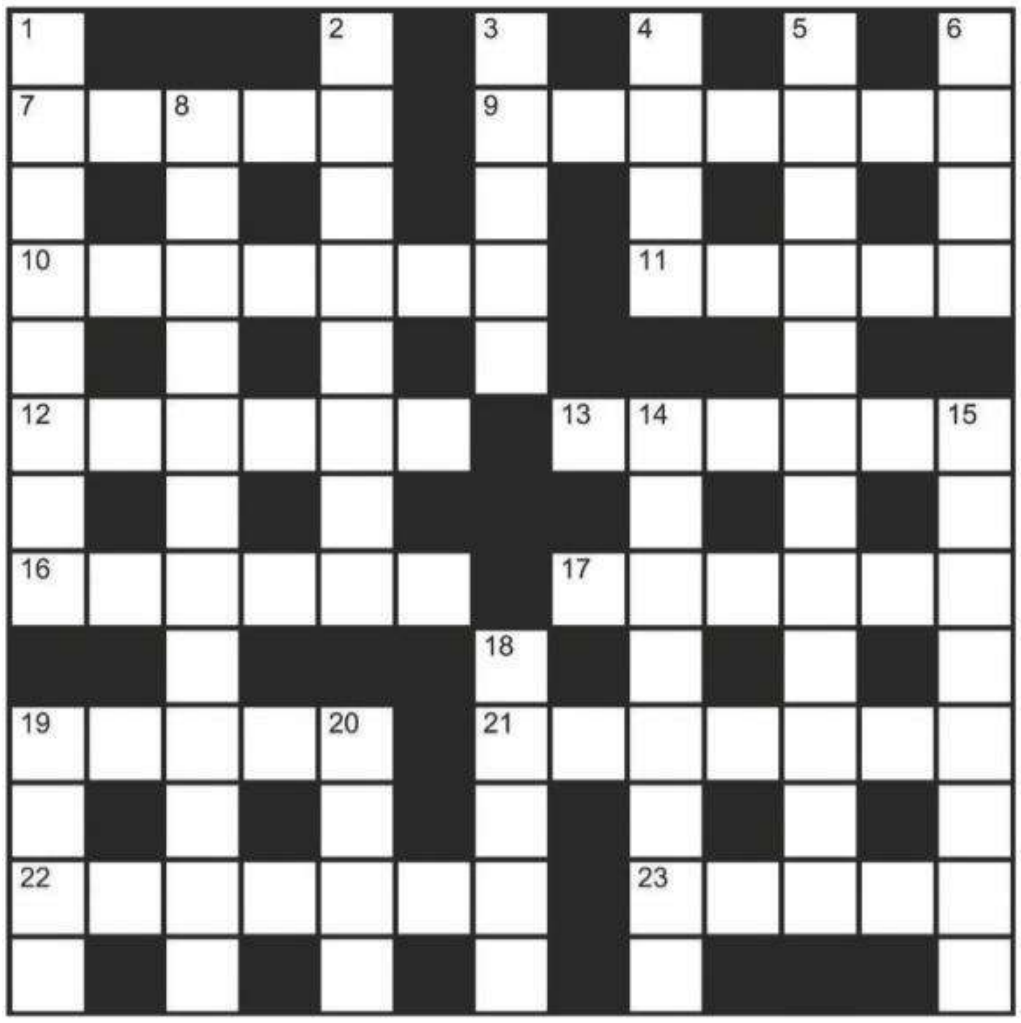
CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

7 A couple of bishops with zero time for another cleric (5)
9 National symbol to raise that woman's temperature (7)
10 Invalidate six – one is in gallery (7)
11 Reporters apply an amount of force (5)
12 Second obligation holding record (6)
13 Betting present is a ball (6)
16 Emphasise a state of nervous tension (6)
17 Reason for earth (6)
19 Object to night manoeuvre (5)
21 Husband – former husband in the past – acquires new shape (7)
22 Dog right for underground worker (7)
23 Terrible key included for sad song (5)

DOWN

1 Sad, vocal composition shows spirit (8)
2 Book about tin, fashioned in fabled place (8)
3 Lavish reward includes dragon (5)
4 Instrument is out of tune – omit start (4)
5 He cures grebe – cooked fast food (12)
6 God of the roses (4)
8 Gamble on father twisting story on a bit of radiation (4,8)
14 For every male animal, I would initially expect a blonde (8)
15 Jeopardise conclusion with rage (8)
18 Small ornament makes cleaner get married (5)
19 Friar's food (4)
20 Good politicians, fluent and shallow (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

PSYCHEDELICS

Discovering the untapped potential of mind-mending trips.

PLUS

MARS CITY

We talk to the architects behind Nüwa City, an incredible vision of a Martian base.

ASTRONOMY FOR BEGINNERS

How to spot the Leo constellation.

ON SALE 17 MAR

SF

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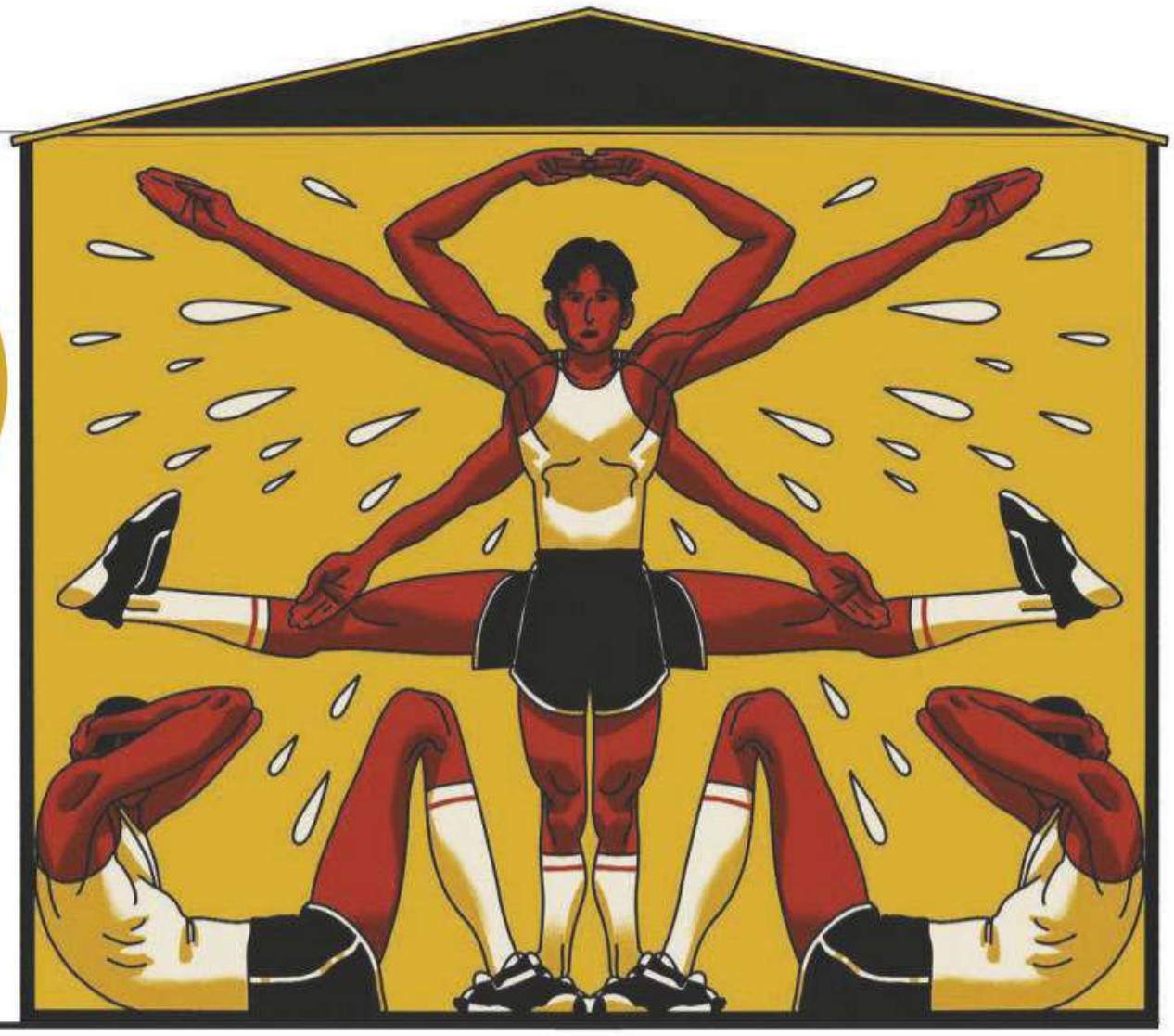

A SCIENTIST'S GUIDE TO LIFE

HOW TO GET FIT AT HOME

BBC ONE

Watch *The Truth About... Getting Fit At Home* with researchers from Liverpool John Moores University. Available now on iPlayer.

DUE TO THE CORONAVIRUS, MORE PEOPLE ARE EXERCISING INDOORS. THIS MONTH, WE ASK EXERCISE RESEARCHERS **MATT COCKS** AND **KATIE HESKETH** HOW TO GET FIT AT HOME

THERE'S NO NEED TO GO THE GYM

Everyone can exercise at home. During the pandemic, life has been different and lots of people have started doing online workouts. Joe Wicks has been popular, for example. We've been exploring how well these apps and online programmes work.

APPS AND ONLINE WORKOUTS CAN BE HELPFUL...

...but they're even better if they're supplemented with a personalised smart watch that guides you through the exercises and gives you feedback on how well you're doing them. We have found that people with these watches exercised more and were less likely to give up than the people without them.

THINK ABOUT EXERCISE INTENSITY

Our research made us realise that it's vital to teach people how to exercise. Exercise intensity is important. Too intense and it will be unpleasant. Too weedy and you won't feel the benefit. We programmed a smart watch so it can guide people to exercise at the right intensity, but you can do the same thing by monitoring your breathing. If you're doing light exercise such as walking, you should be able to sing. If you're doing high-intensity interval training, you should be so breathless that you can't speak.

THERE IS NO 'BEST EXERCISE'

There's only what's best for you. Short bursts of high-intensity exercise are great, but they aren't for everyone. Similarly, not everyone has time for a lengthy walk. Think about how much time you have, how hard you want to work and the sorts of exercise you enjoy. As long as you hit these three things, it doesn't matter what you do. A 20-minute high-intensity interval session can be just as good for you as a 30- to 50-minute walk.

YOU DON'T NEED A LOT OF SPACE

If you have a room that's tall enough to stand in, and long enough to lie down in, then it's big enough. Star jumps and sit-ups don't take much room.

AIM FOR TWO SESSIONS A WEEK

Our research suggests that people who do two exercise sessions a week improve their fitness more than those who train once a week or not at all, and the improvement is pretty similar to people who train three times a week.

YOU DON'T NEED ANY SPECIAL EQUIPMENT

Instead, as you get fitter, modify the exercises that you do. Increase the intensity or duration. You don't need fancy equipment for this.

STAY MOTIVATED

Set yourself an achievable goal such as, "in 12 weeks' time, I want to be able to jog for 10 minutes without stopping." Start small and build up incrementally. Tell your family and friends what you are up to so they can prise you off the sofa if you're having a bad day.

EXERCISING BEFORE BREAKFAST COULD BE HELPFUL

There's some evidence to suggest that if you exercise after a meal, the body burns more carbohydrate, but if you exercise before a meal, the body burns more fat. This suggests that exercising before breakfast could be a good idea, but be careful – it makes some people dizzy so it's not for everyone.

SIT-UPS ALONE WILL NOT GIVE YOU A SIX PACK

It's really difficult to get a six pack. You need good nutrition and low levels of body fat. Eating well and bouts of long, low-intensity cardiovascular exercise can help. SF

MATT COCKS and KATIE HESKETH
Matt and Katie research exercise and health at Liverpool John Moores University. ***Interviewed by Dr Helen Pilcher.***

NEED TO KNOW...

1

Exercise intensity is really important. Monitor your breathing to establish how hard you're working.

2

Getting a six pack is really hard (don't believe social media posts). Instead, focus on eating well and doing cardio.

3

Start with online apps and workouts – find one that you enjoy and aim to exercise twice a week.

ILLUSTRATION: AVALON NUOVO

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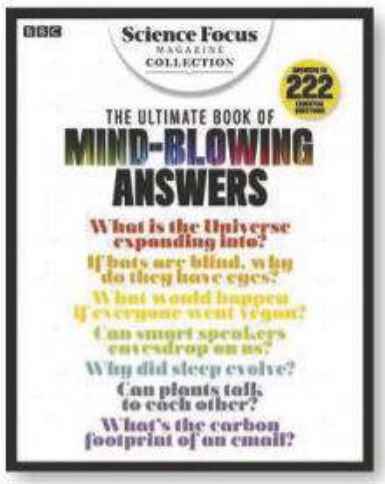
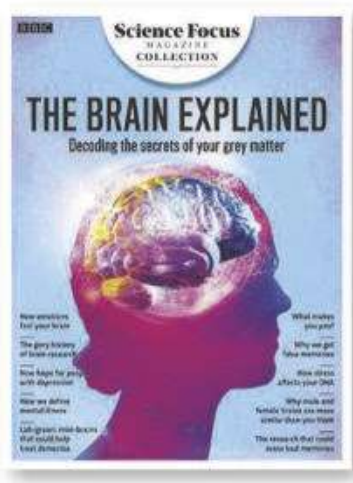

Science Focus
MAGAZINE
COLLECTION
222
THE ULTIMATE BOOK OF
MIND-BLOWING
ANSWERS
What is the Universe expanding into?
If bats are blind, why do they have eyes?
What would happen if everyone went vegan?
Can smart speakers eavesdrop on us?
Why did sleep evolve?
Can plants talk to each other?
What's the carbon footprint of an email?

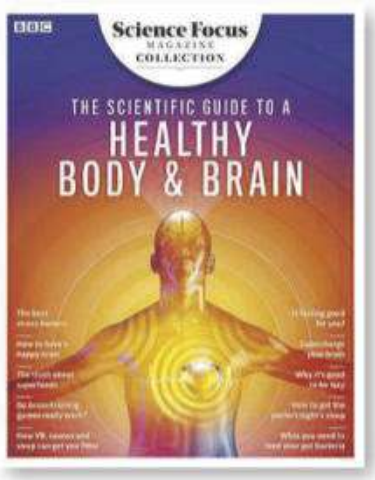
Truth is often stranger than fiction, as the 222 mind-blowing answers to what seem like simple questions demonstrate in this Special Edition.

Be astounded by incredible insights from the cutting edge of science, and meet the radical researchers who are stretching our knowledge to the limit.

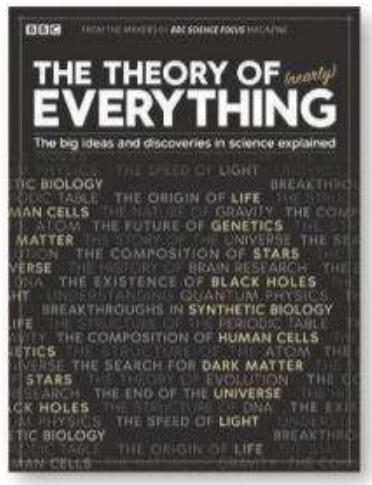


Find out about the extraordinary abilities of the brain, the evolution of intelligence and the latest research into mental health.

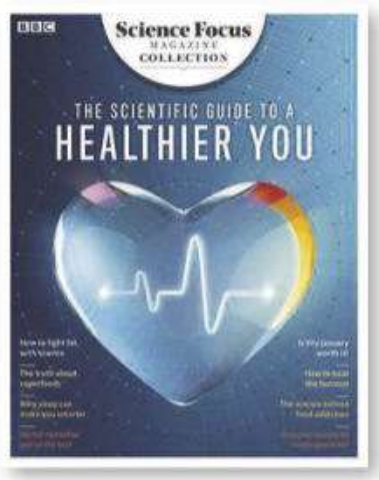
Discover more about the missions that will help unravel the mysteries of the cosmos as they venture everywhere from our closest neighbours to the galaxies far, far, away.



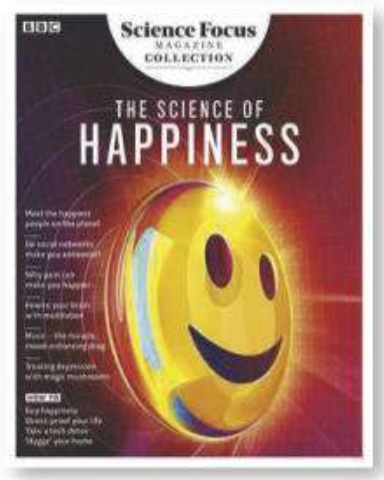
Allow science to show you the best ways to keep your brain sharp and your waistline slim, while staying fit, healthy and happy.



This special issue explains the fundamental concepts of science, and reveals the latest cutting-edge research that will change our world.



Experts reveal the science behind what really works when it comes to losing weight, eating right, keeping fit and sleeping well.



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